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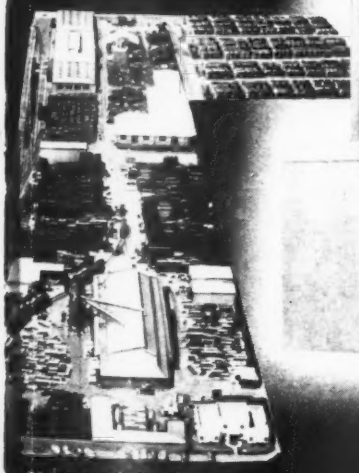

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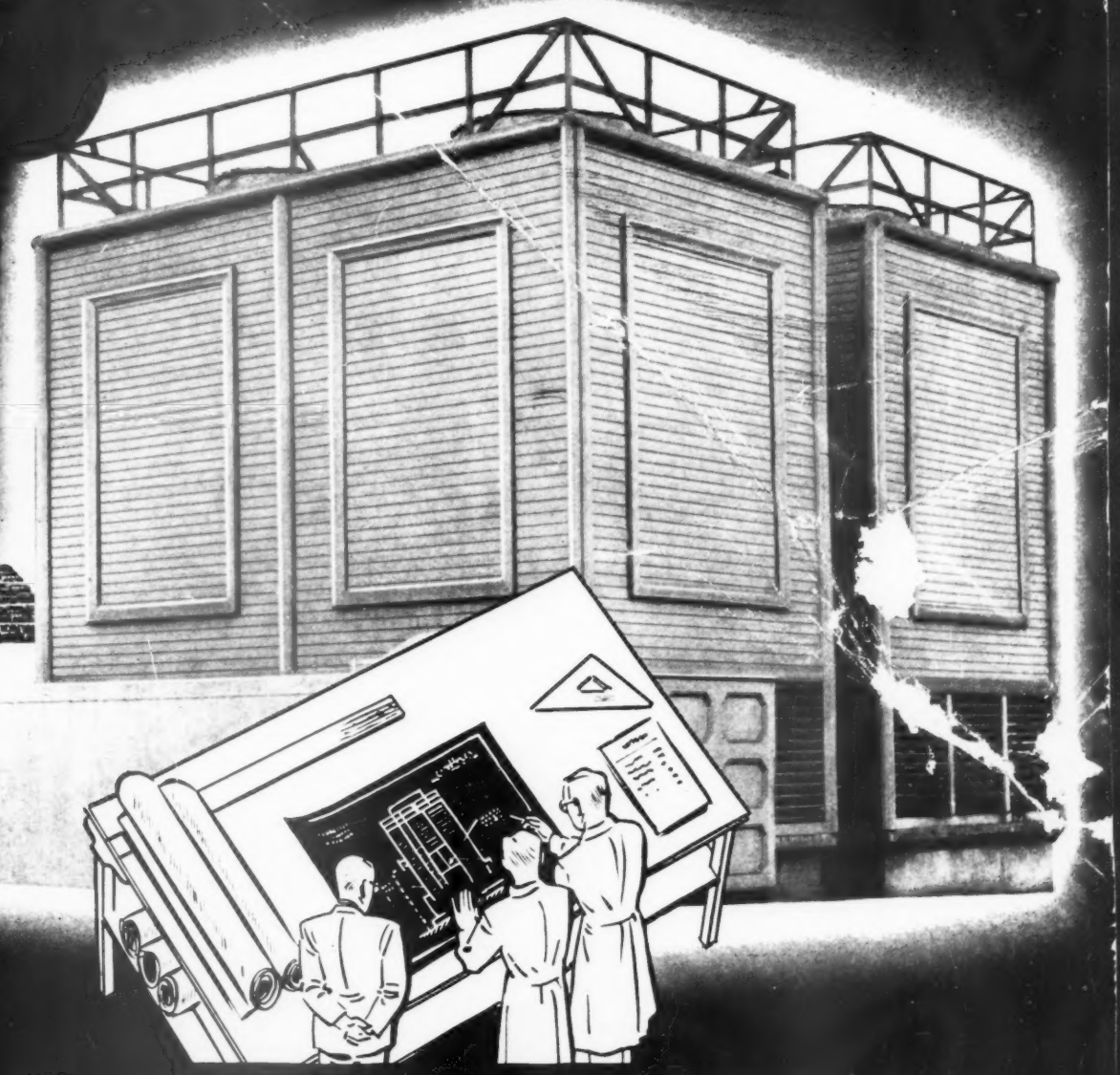

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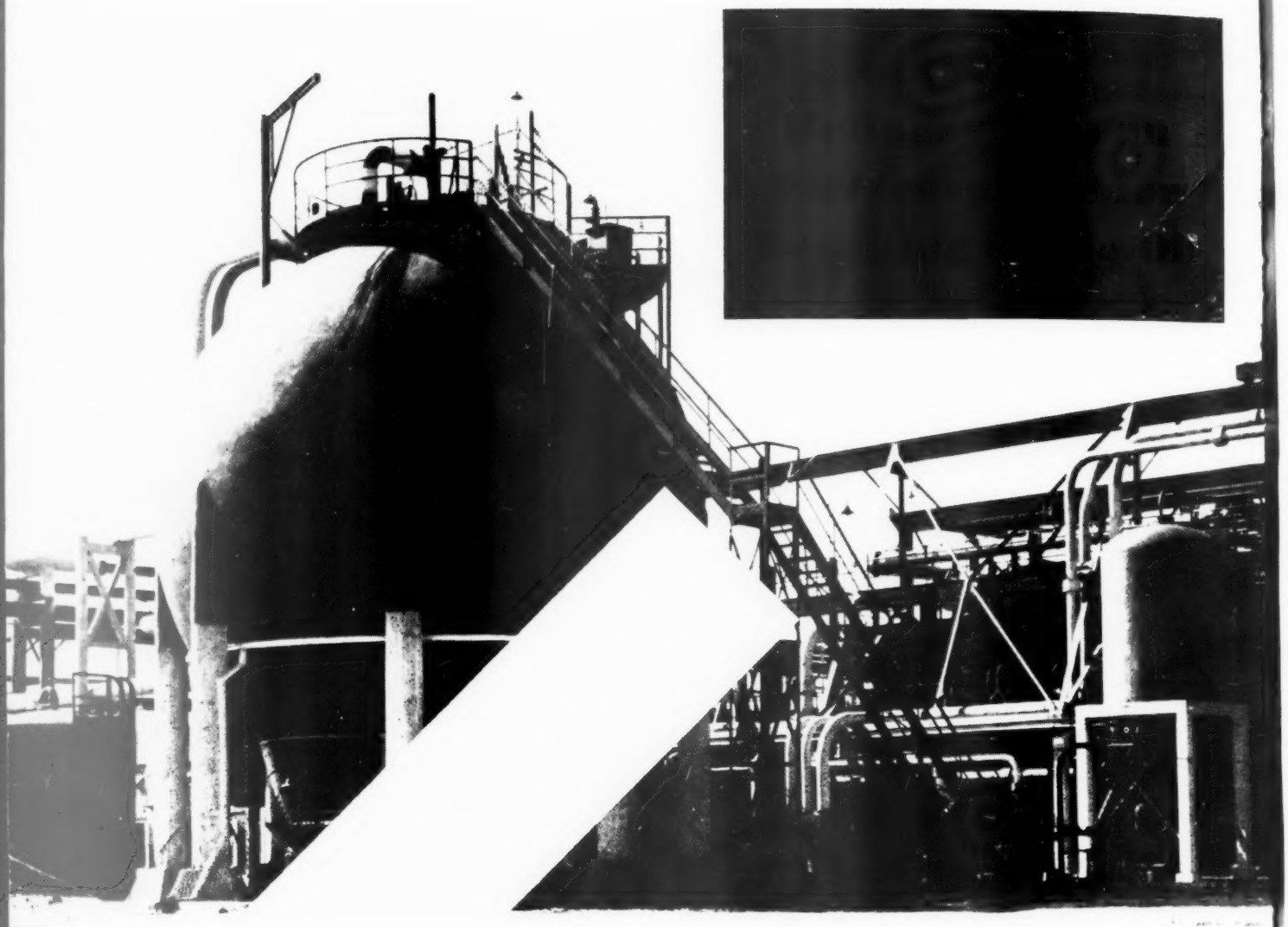

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The installation is designed to desalt
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.. The mixture, 95 per cent oil and 5 per cent
through an emulsifier and then into a high-voltage
electric field. The water particles and brine particles are el
trically attracted and coalesced. The coalesced masses then set
by gravity to the bottom of the vessel and are drawn off.

The desalting facilities make it possible for the cracki
unit to perform efficiently at constant maximum throughp

The Electrosphere shown above is a specially designed Chica
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sq. in. working pressure. This view shows the desalting tra
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APRIL • 1948

VOLUME XIX NUMBER 7

the Petroleum Engineer

...ds for Operating Men

MEETINGS

Apr. 26-29—Am. Assn of Petroleum Geologists, Soc. of Economic Paleontologists & Mineralologists, & Soc. of Exploration Geophysicists, annual meeting, Denver, Colo.

Apr. 27-28—Mid-Continent Oil & Gas Assn, Annual Federal Tax Forum, Blackstone Hotel, Fort Worth, Texas.

Apr. 28-30—Liquefied Petroleum Gas Assn, annual convention, Kansas City, Mo.

May 3—Nomads, Louis Sherry's, 50th Street and Park Avenue, New York City.

May 4-5—AGA, Natural Gas Department, Spring meeting, Rice Hotel, Houston, Texas.

May 5-7—Interstate Oil Compact Commission, quarterly meeting, Chicago, Ill.

May 6-7—API, Pacific coast production division, Biltmore Hotel, Los Angeles, California.

May 10—Nomads, The Houston Club, Houston, Texas.

May 10-13—API, Refining Division, midyear, Benjamin Franklin Hotel, Philadelphia, Pennsylvania.

May 12—Nomads, Jonathan Club, Los Angeles, California.

May 12—Institute of Petroleum, Manson House, 26, Portland Place, London, W. I.

May 15-22—International Petroleum Exposition, Tulsa, Okla.

May 31-June 6—LPG Assn, annual convention and trade show, Sacramento, Calif.

June 2-4—Gas Technology Short Course, Texas A & I College, Kingsville.

June 6-8—Petroleum Equipment Supplier's Assn, annual meeting, Broadmoor Hotel, Colorado Springs, Colo.

June 7—Nomads, Louis Sherry's, 50th Street and Park Avenue, New York City.

June 21-25—ASTM, 51st annual meeting, Book-Cadillac Hotel, Detroit, Mich.

June 30-July 2—API, Eastern production division, Greenbrier Hotel, White Sulphur Springs, West Virginia.

June 30-July 3—Canadian Gas Assn, annual meeting, Jasper Park Lodge, Jasper, Alberta.

Sept. 13-17—Instrument Society of America, conference and exhibit, Convention Hall, Philadelphia, Pa.

Sept. 14-16—Pacific Coast Gas Assn, annual meeting, Hotel Casa del Rey, Santa Cruz, Calif.

Oct. 4-9—AGA, technical section, annual meeting, Ambassador Hotel, Atlantic City, N. J.

Oct. 11-13—National Lubricating Grease Institute, annual meeting, Edgewater Beach Hotel, Chicago, Ill.

Oct. 11-13—American Assn of Oilwell Drilling Contractors, annual meeting, Rice Hotel, Houston, Texas.

Oct. 14-15—Texas Mid-Continent Oil & Gas Assn, annual meeting, Fort Worth.

Nov. 8-11—API, annual meeting, Stevens Hotel, Chicago, Ill.

Nov. 15-18—American Oil Chemists Society, fall meeting, Pennsylvania Hotel, New York.

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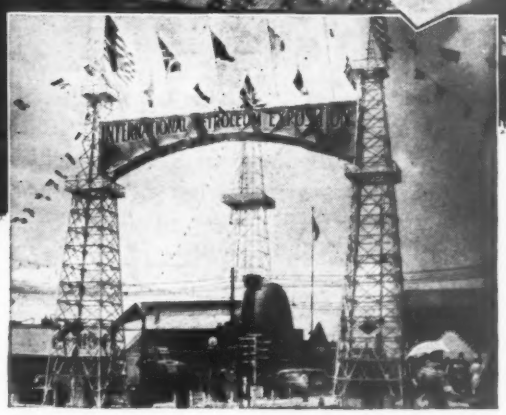

World's Fair of the Oil Industry

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INTERNATIONAL PETROLEUM EXPOSITION

TULSA, OKLAHOMA, U.S.A., MAY 15-22, 1948

STRETCHING OUR OIL RESERVES

Orthodox thinking in regard to conservation of our national oil reserves is inclined to be narrow in its concept. Too often it is confined to methods of producing crude oil with a minimum of waste and to increasing the ultimate recovery of oil by pressure maintenance, secondary recovery, or other improved field practices. This is a narrow view that considers but one phase of the subject. Conservation of oil in its broadest sense is far-reaching, for it embraces refining and processing crude oil and its products, and the effective utilization of these products. Every improvement that comes along, whether in production, refining, or utilization, enhances the value—from a power standpoint—of a barrel of crude and in effect increases the potential volume of our national petroleum reserves.

Motor fuel such as gasoline is one of the vital petroleum products that touches every phase of our national life. If more power (more miles per gallon) could be obtained from a gallon of motor fuel it would be equivalent to increasing our motor fuel reserves and consequently our national crude reserves.

How to get more power from a gallon of motor fuel is a problem not only in fuel processing but also in engine design. Obviously the problem of fuel saving, which is also one of oil conservation, is one that reaches beyond the petroleum industry. In this instance, it reaches into the automotive industry.

It has just been made public that the Research Laboratories Division of the General Motors Corporation has made a series of tests with high compression engines. The results are outlined in a paper by J. M. Campbell and L. L. Withrow: "Engines and Fuels for Higher Efficiency" delivered at the Annual Meeting of the National Gasoline Association of America at Fort Worth last month. According to the authors: "Since 1930 the average efficiency of fuel utilization in passenger car engines expressed in ton-miles per gallon of gasoline, has increased by more than 30 per cent. This very significant development is the result of the combined efforts of the Petroleum and Automotive industries to raise the octane ratings of gasolines and to build engines to take full advantage of these improvements in fuel quality.

"Looking toward the future, General Motors Corporation has run full-scale automobile tests with high compression engines showing that further gains in fuel utilization of the same order of magnitude as those obtained in the past are still possible by continued development of both fuels and engines by the Petroleum and Automotive industries."

The authors point out that: "Over the past several years considerable progress has been made in the efficiency of fuel utilization in automotive engines. One measure of the increase in efficiency of fuel utilization is given by the trend in average fuel economy expressed in ton-miles per gallon.

From the standpoint of conservation, here is a significant note: "Gains in fuel economy in the order of from 10 to 25 percent are possible at octane levels not much above those established by some present premium gasolines and that still greater gains can be made at higher octane number levels. These gains have been demonstrated repeatedly in several engines all using the high-compression principle plus engine design changes incident to the use of higher compression ratio and supported by thousands of miles of operation in different makes of cars and under a wide range of conditions.

"In order to take advantage of these gains which are technically possible, we recognize that economic considerations must finally be taken into account. The gains that can be made in fuel economy must more than offset the increase in cost of the high octane fuel required in order to create a balance that is favorable toward increasing compression ratio. We believe, however, that gains running as high as 40 percent in fuel economy without loss in performance are sufficient to offset a considerable increase in cost of the fuel and that such gains merit the serious consideration of the petroleum industry. The problem of introducing fuels on a nation-wide basis that will permit the introduction of automobiles capable of taking full advantage of such fuels is at once a challenge and an opportunity for continued progressive development of fuels and engines such as has occurred over the past twenty years."

Regarding this development, the authors "think it is a very worthwhile thing because if we can get the same amount of power from fewer gallons of gasoline, it is like discovering new oil fields, it is part of the conservation of national resources, and we are going to push it along one way or the other."

According to the results obtained in these tests, here is a potential saving in motor fuel that is tantamount to an increase in our national motor fuel reserves of as much as 40 percent. This saving, when it is effected, is equivalent to bringing in new fields. It stretches national oil reserves.—K. C. S.

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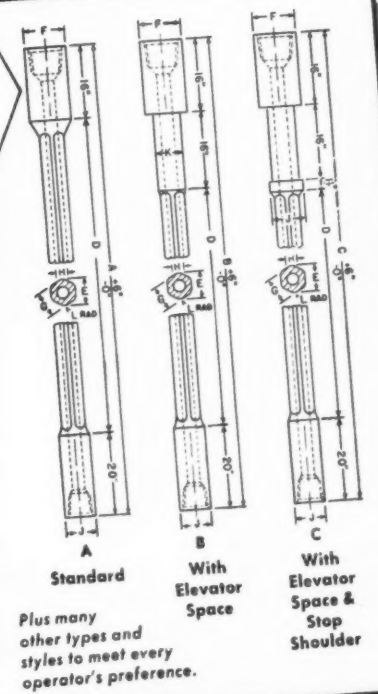

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SCANNING WASHINGTON'S OIL HORIZON

By MILBURN PETTY

WASHINGTON—The petroleum industry came through the winter without too-serious difficulty and now faces the gasoline season with record-high production and stocks of motor fuel—but the political climate here for oil and gas in still unfavorable with no signs of improving.

Small credit is given the industry for its magnificent job. Instead, there is still talk on Capitol Hill that "something ought to be done about the oil situation." And it isn't just an echo of fuel oil complaints. But, unless war comes much nearer, there won't be any control legislation passed this session.

Republicans are counting on the public's antipathy to OPA as a factor in the coming elections. So, they would be most reluctant to neutralize this issue by restoring similar controls. Likewise for political reasons, President Truman may keep on asking for price and rationing controls on oil and other critical items but he isn't pressing for such action. That leaves Truman in a "I-told-you-so" position later, if shortages become acute.

There is a good chance, however, that Congress or the President soon will take definite steps to develop a national oil policy, as was pointed out here in February. Plenty of congressmen are worked up about the oil situation; they won't vote controls, yet they want something to point to when they go back home. So, the way out is to launch a comprehensive oil investigation with report and recommendations later—if Truman doesn't beat them to the punch with an oil study like the Baruch Committee did on rubber in 1942.

The military preparedness program has dimmed the industry's optimism about the supply-demand outlook, both from the standpoint of increased oil requirements and further demands on steel, which is needed to produce more oil. (Privately, military procurement officers have told other agencies that the preparedness program will substantially increase the oil takings of the armed forces, warning that the only way such increases can be met—at present levels of production and refining operations—is by curtailing civilian consumption.)

Even the most pessimistic oil man, however, disagrees violently with the direful statements of some government officials. For example, Interior Secretary Krug has said that the United States currently is about 15 per cent short of crude to meet demand (and this did not count in requirements of the Marshall Plan or the preparedness program, the impacts of which have not been felt yet).

Also, Krug has been telling congressional oil committees that "luxury" uses of oil must be curtailed in order that "essential" demands can be met, although he didn't say how. Later, Krug explained to newspapermen that he hoped the industry would include some sort of priority list in its voluntary allocations program, so that "essential" users would be taken care of. If not, Krug added, then government controls would be needed.

Along this same line, Krug has appealed to all regulatory agencies and transportation companies not to substitute buses for street cars and interurban lines "until a more adequate supply of petroleum products is assured."

All of this smacked of "end use" control, prompting a protest from Russell B. Brown, counsel for the Independent Petroleum Association of America. Brown challenged Interior Department's right "to pass judgment on the use which is to be made of petroleum products."

●

PRODDED by congressional oil committees, President Truman had Secretary Krug write to the oil state governors urging that they study the productive capacity of their fields and make sure that each was "allowed to produce at its maximum efficient rate as determined by sound engineering principles."

Several days later, though, Krug told Senator Wherry's Small Business Committee that he thought all the states were producing at or about MER, citing Arkansas, Louisiana, and Mississippi as among those producing above MER now. (Krug didn't give the basis of his statement, except to say that it was the consensus of federal and state officials with whom he had talked.) If Krug is correct, then the oil situation won't be improved by the MER study he has requested the states to make. Indeed, it might mean cutbacks in allowables, which would reduce supply. And if production is now right at MER, the maximum possible, a formal finding and announcement of that fact will further arouse the public's fears of an oil shortage, although it would support the industry's plea for more steel.

Reexamination of MER's is only one of the strings to Senator Wherry's bow as he seeks more oil production. Wherry started pushing that idea after President Truman had rejected his demand that the Connally "Hot" Oil Law be suspended. Another move by Wherry was to press A. G. White, Bureau of Mines' forecaster, to estimate "real" demand instead of probable supply, arguing that a higher demand figure would be an incentive to produce more crude and transport it to get all refining capacity on stream. Wherry's figures indicate about 30 per cent of independent refining capacity is not being used for lack of crude.

So, it can be expected that there will be increased pressure on the states to raise their allowables, one way or another.

●

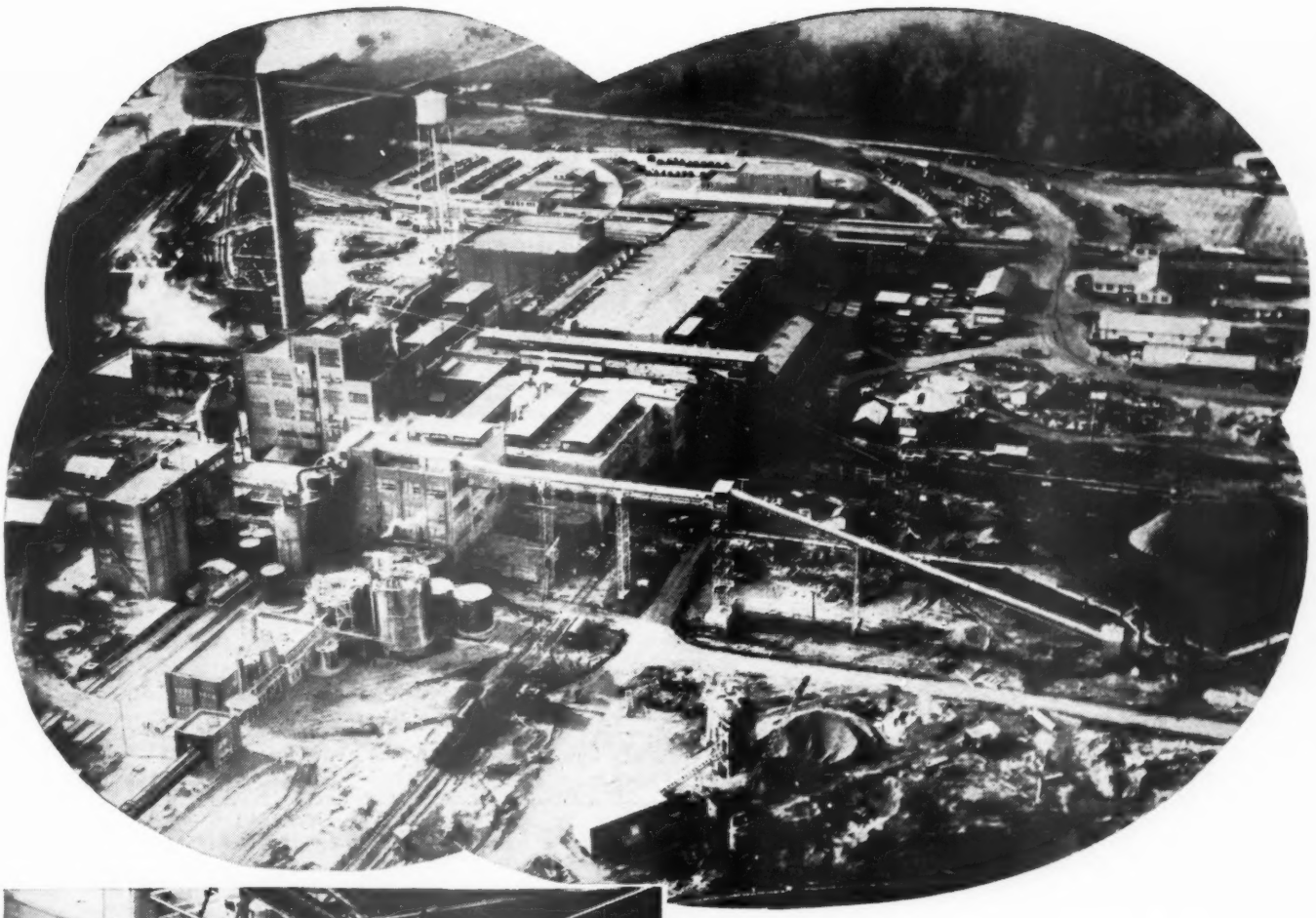
URGENCY of the international situation and the military's anxiety to approach as nearly as possible self-sufficiency in oil—at least in this hemisphere—will influence many decisions in the months ahead.

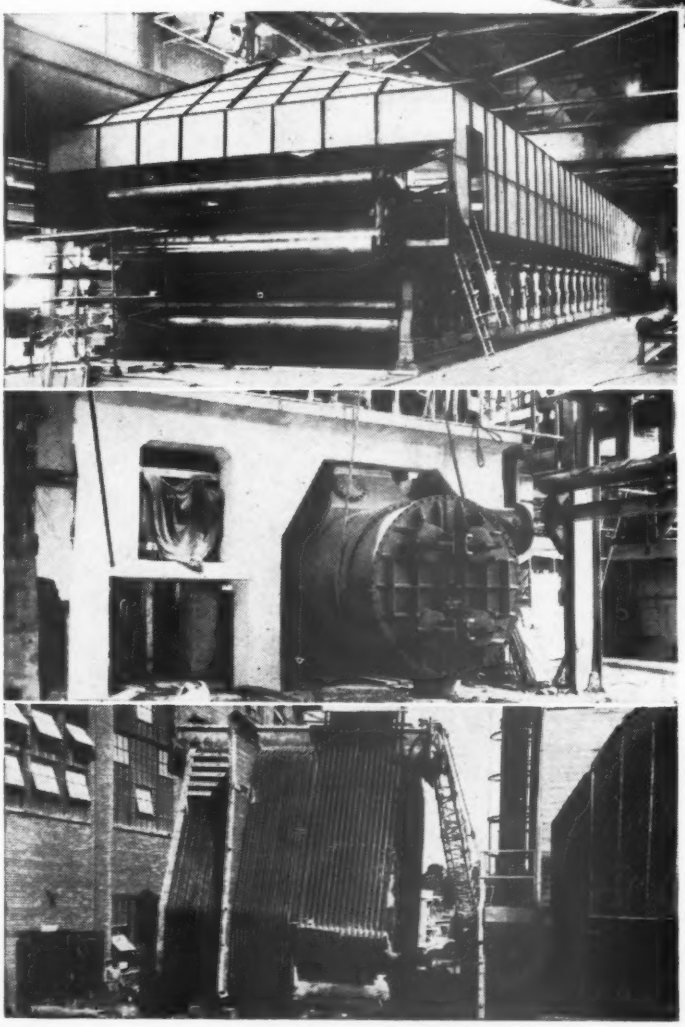
For example, pressure from the military may bring about enactment of the $400,000,000 synthetic fuels bill, which proposes that the government build up to 30,000 bbl a day of plant capacity if private companies are unwilling to use their own or government loans for such projects.

Defense Secretary Forrestal says the next war would require at least 2,000,000 bbl a day more oil than would be available from foreseeable U. S. production, which means that much more would be needed from accessible areas in Latin America. So, the military's views will be persuasive in decisions on development of oil resources in those countries. It was pressure from military leaders that prodded the State Department into starting talks with Mexico resulting in the first proposal for reentry of American oil operators to develop Mexican oil resources. While the proposed 20 per cent interest in oil produced was not considered sufficient incentive, it was welcomed as the starting point for further negotiations.

Likewise, Forrestal's view that tidelands oil should be developed—and fast, may be the turning point in the federal vs. state controversy since that is a good argument for passage of the states rights' tidelands bill to clear up titles.

Military backing may also clear the way for construction of a new crude oil line from West Texas to California, possibly with a branch line running down to meet it from the Rocky Mountain area as has been considered. A speed-up in the Alaskan oil search is another probability.





How to Multiply a Paper Mill by 2

At the Southland Paper Mills at Lufkin, Texas, above, Brown & Root, Inc., was given the problem of doubling the newsprint output.

175 Tons Daily x 2 = 350 Tons Daily

Doubling the production involved very substantial increases in power output, expansion of existing buildings, construction of new buildings, installation of new machinery, moving of old facilities, work of every type—and all the time manufacture of critical newsprint had to go on.

Southland Paper Mills Schedule Uninterrupted

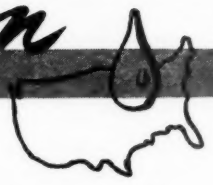
Our supervisors and crews have shown such fine teamwork with Southland's able personnel that production of Texas' greatest newsprint mill has continued at peak levels.

Bring your complicated expansion or new construction problems to Brown & Root, Inc., whose experience and resources in the Southwest are unsurpassed.

BROWN & ROOT, Inc.

P. O. Box 2634 **Houston, Texas**

national petroleum situation



By H. J. STRUTH*,
Petroleum Economist

GREATER GASOLINE SUPPLY. Increased refining operations in the first quarter of the year have materially increased the gasoline supply. While demand increased 7 per cent, refinery output rose 10 per cent and natural gasoline production was 14 per cent above last year. Motor fuel stocks, March 31, of 107,250,000 bbl were about 19,000,000 bbl above the January 1 level and 5,000,000 bbl greater than last year. Projections of summer gasoline demand indicate gain over last year of 7.4 per cent, but increased supplies are expected to lift stocks at close of third quarter to about 91,000,000 bbl. This indicates that stocks at summer's end will be about 11,000,000 bbl above last year.

HEAVY DISTILLATE DEMAND. Prospective demand for distillate fuels next winter may be about 8.8 per cent above last year. Indications are that the industry can meet this large increase through maximum refining operations and necessary fall and winter yield adjustments. Projections of supply and demand for this product indicate that supply will be on about a break-even basis next winter. Stocks at the close of March, 1949 are expected to be about 28,000,000 bbl, which would be about 2,000,000 bbl above the March 31, 1948 level. Improved transportation facilities contemplate earlier movements to critical areas and may avoid a repetition of last winter's difficulties. Situation will continue tight this year but supply outlook is materially improved over earlier forecasts.

MORE IMPORTS. Imports of all oils are expected to exceed exports this year by an average of about 70,000 bbl daily. Projections indicate likelihood that imports will average 495,000 bbl daily, while exports will be about 425,000 bbl daily. This year's oil supply is expected to show an increase over last year of about 411,000 bbl daily. The increase will come from excess imports 70,000 bbl; increased crude output 305,000 bbl; increased natural gasoline output 36,000 bbl. Domestic demand will average about 391,000 bbl more than last year, leaving a net gain in supply of 20,000 bbl daily. First quarter supply was 11 per cent above 1947.

*Editor, *The Petroleum Data Book.*

Comparative Statistics, March, 1948

*All figures are computed on a Bureau of Mines' Basis**

	March 1948℗	Feb. 1948℗	March 1947	This year to date	Last year to date	Per cent change
Wells drilling	4,400	4,400	3,730	4,400	3,730	+18
Total wells drilled	2,593	2,393	2,419	8,013	7,203	+11
Development wells	2,049	1,864	1,901	6,218	5,665	+10
Oil	1,488	1,329	1,292	4,457	3,765	+18
Gas	170	162	252	539	782	−31
Dry	391	373	357	1,222	1,118	+ 9
Per cent dry	19.1	20.0	18.8	19.7	19.7	0
Service wells	159	144	154	521	414	+26
Wildcat wells	385	385	364	1,274	1,124	+13
Oil	55	62	57	177	159	+11
Gas	22	18	11	59	35	+69
Dry	308	305	296	1,038	930	+12
Per cent dry	80.0	79.2	81.3	81.5	82.7	− 1.2
Crude supply	173,300	¶162,800	161,423	508,308	457,123	+11
Daily average	5,590	5,614	5,207	5,586	5,079	
Crude demand‡	172,520	¶163,920	157,354	509,460	452,319	+13
Daily average	5,565	5,652	5,076	5,598	5,026	
Crude stocks	229,500	¶228,720	234,980	229,500	234,980	− 2
Days supply	41	40	46	41	46	
Natural gasoline production	12,150	11,500	10,953	35,647	31,388	+14
Daily average	392	397	353	392	349	
Motor fuel production	71,200	67,550	66,701	212,562	193,090	+10
Daily average	2,297	2,329	2,152	2,336	2,145	
Gasoline yield, per cent	38.3	38.2	39.3	38.7	39.6	− 0.9
Motor fuel demand‡	69,610	¶59,540	64,479	192,773	180,388	+ 7
Daily average	2,245	2,053	2,080	2,118	2,004	
Motor fuel stocks^	107,250	105,660	102,217	107,250	102,217	+ 5
Days supply	48	51	49	48	49	
Fuel oil production	73,630	70,810	63,453	217,585	180,110	+21
Daily average	2,375	2,442	2,047	2,391	2,001	
Fuel oil demand‡	82,160	86,630	78,265	262,072	241,834	+ 8
Daily average	2,650	2,987	2,525	2,880	2,687	
Fuel oil stocks	74,600	¶77,630	68,826	74,600	68,826	+ 8
Days supply	28	26	27	28	27	
Refinery still runs	165,400	157,200	150,120	488,396	431,970	+13
Daily average	5,335	5,421	4,843	5,367	4,800	
All refined stocks	255,450	¶257,530	246,063	255,450	246,063	+ 4
Days supply	42	41	43	42	43	

Supply and Demand—All Oils

	March 1948℗	Feb. 1948℗	March 1947	This year to date	Last year to date	Per cent change
Total supply, all oils	191,800	¶180,350	178,602	561,884	506,701	+11
Daily average	6,187	6,219	5,761	6,175	5,630	
Total demand‡, all oils	193,100	184,870	179,891	577,733	532,527	+ 8
Daily average	6,229	6,375	5,803	6,349	5,917	
Change in stocks (total)	− 1,300	− 4,520	− 1,289	−15,849	−25,826	

Current Crude Oil Prices

U. S. average	$2.61	Louisiana	$2.62
Texas	2.61	Arkansas	2.43
California	2.42	New Mexico	2.40
Oklahoma	2.63	Mississippi	2.42
Kansas	2.62	Illinois	2.76
		Other states	3.15

Basic crude prices:

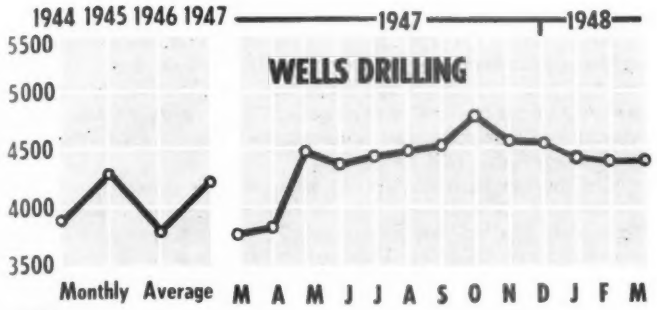
Oklahoma-Kansas (36 gr.)	$2.57
Texas Gulf Coast (36 gr.)	2.86
East Texas	2.65
West Texas (36 gr.)	2.44
California Signal Hill (26 gr.)	2.41
Pennsylvania, Bradford	5.00

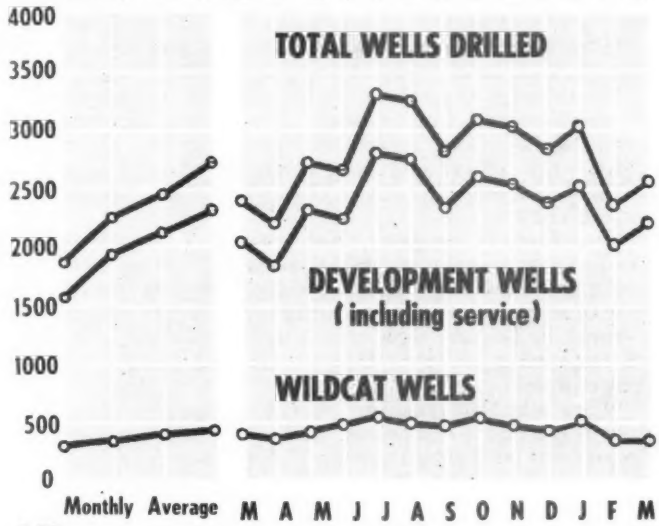
Drilling and Production Statistics by States

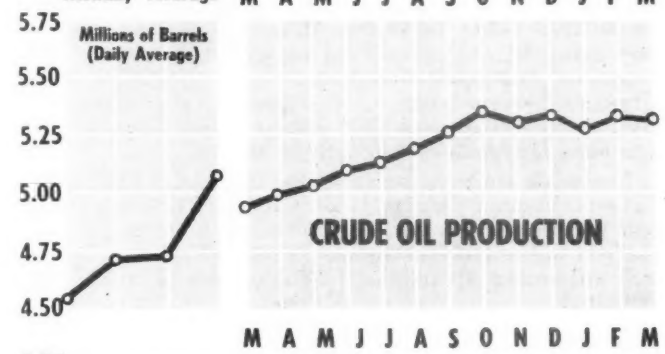
	March 1948℗	Feb. 1948℗	March 1947	This year to date	Last year to date	Per cent change
Wells drilled (excl service)	2,434	2,249	2,265	7,492	6,789	+ 10
Arkansas	15	28	21	78	58	+ 34
California	204	213	125	633	450	+ 41
Illinois	126	154	166	453	458	— 1
Kansas	164	197	192	605	590	+ 3
Louisiana	156	123	93	423	289	+ 46
Mississippi	28	32	30	95	87	+ 9
New Mexico	55	32	52	147	133	+ 11
Oklahoma	278	260	310	872	970	— 10
Texas	851	715	706	2,458	2,089	+ 18
Other states	557	495	570	1,728	1,665	+ 4
Wildcats drilled (incl above)	385	385	364	1,274	1,124	+ 13
Arkansas	4	7	3	22	11	+100
California	20	25	26	71	76	— 7
Illinois	23	33	21	84	81	+ 4
Kansas	22	30	24	87	78	+ 12
Louisiana	20	20	23	56	57	— 2
Mississippi	10	6	2	25	22	+ 14
New Mexico	6	3	3	12	13	— 8
Oklahoma	52	52	58	188	221	— 15
Texas	167	149	159	538	415	+ 30
Other states	61	60	45	191	150	+ 27
Daily crude production	5,316	¶5,341	4,908	5,313	4,796	+ 11
Arkansas	84	¶85	82	84	80	+ 5
California	940	930	904	934	896	+ 4
Illinois	170	175	186	172	190	— 9
Kansas	249	281	279	273	273	0
Louisiana	471	¶471	422	471	419	+ 12
Mississippi	118	114	86	115	86	+ 34
New Mexico	130	¶127	106	127	105	+ 21
Oklahoma	399	¶405	380	398	372	+ 7
Texas	2,392	¶2,395	2,145	2,380	2,057	+ 16
Wyoming	145	¶141	113	143	111	+ 29
Other states	218	¶217	205	216	207	+ 4

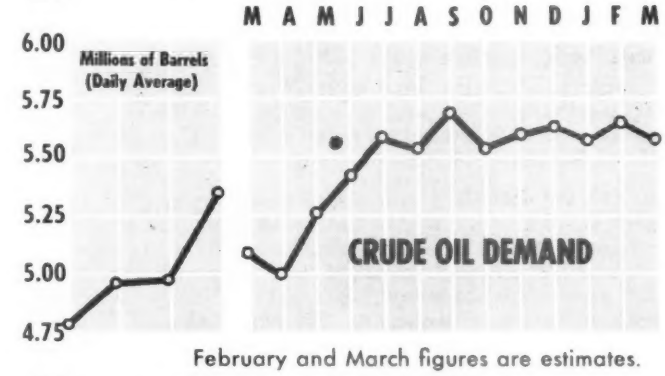
*Unless otherwise stated all figures represent thousands of barrels.
‡Total demand, including exports.
℗–Preliminary.
^Includes finished and natural gasoline.
*Includes domestic production and imports.
¶Revised.

Preliminary estimates based upon data supplied by American Petroleum Institute, U. S. Bureau of Mines, State Agencies, and other official sources.

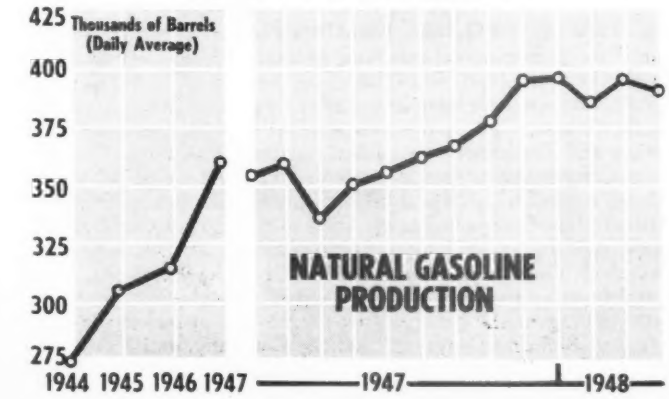


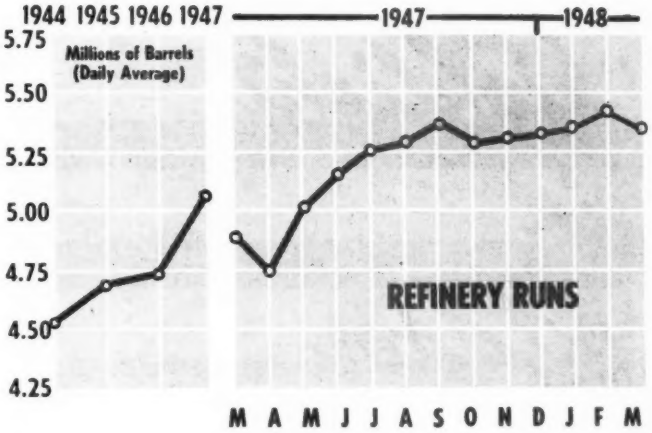


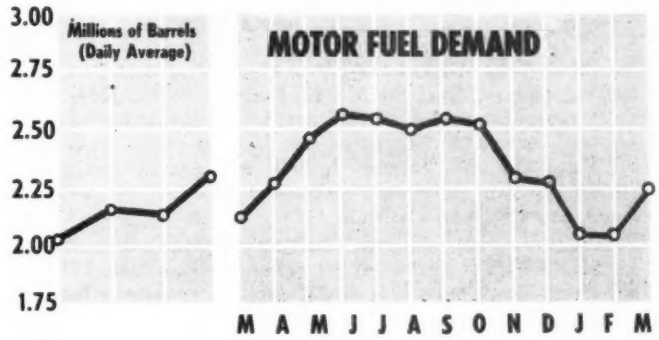


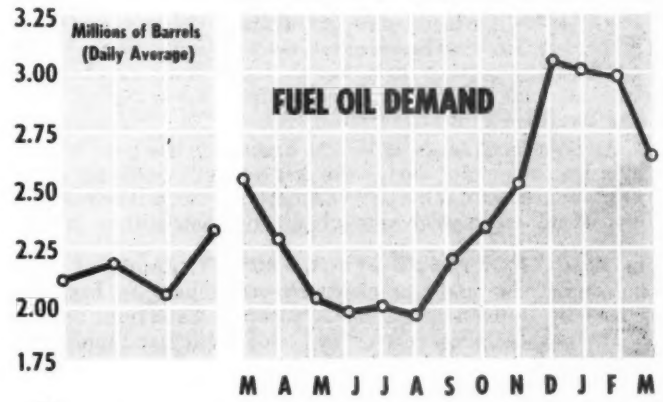


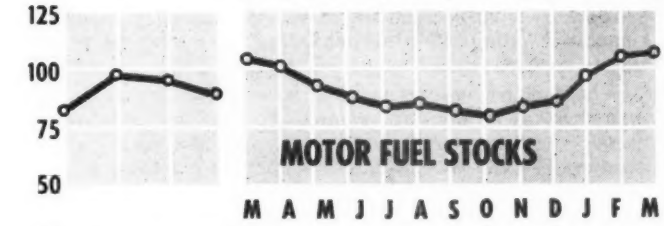
February and March figures are estimates.

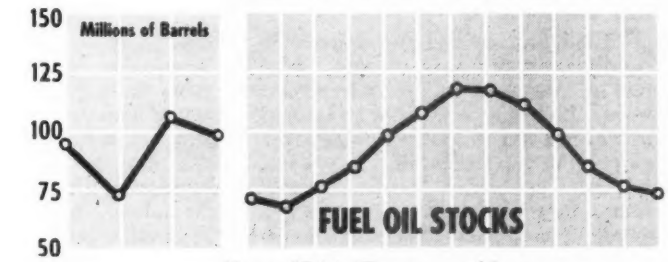




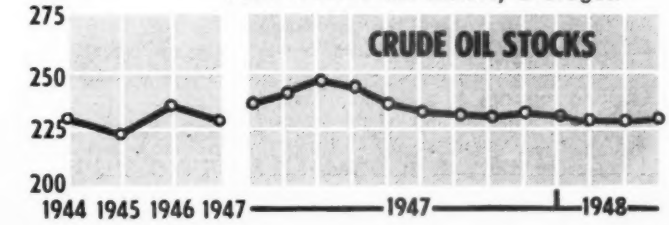








Years 1944-47 are monthly averages.



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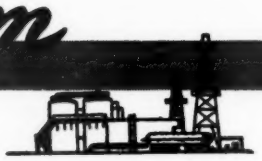


● **TO IMPORT MIDDLE EAST OIL.** Plans to increase its importation of crude oil from the Middle East starting in May, to augment needed supplies in this country, are announced by the Socony-Vacuum Oil Company, Inc. Imports will average 17,000 bbl a day and after January 1, 1949, will increase gradually to 40,000 bbl. The increased shipments of crude oil will come mostly from Iran and Kuwait.

Socony-Vacuum has been bringing in crude oil from Saudi-Arabia to its Paulsboro (N.J.) refinery since July, 1947, and importing crude from Iran and Kuwait is a continuation of the company's efforts to meet the unprecedented demand for petroleum products in this country. The use of Iranian crude at Paulsboro will release some quantities of Texas crude for use in the company's refineries in midwestern United States to make gasoline and heating fuels. Finished petroleum products from Iranian crude will be marketed in New York, New England, and the Middle Atlantic States.

An occasional cargo of Middle East crude has been imported by a few companies during the last several months for experimental purposes but Socony-Vacuum's project will be one of the first whereby a regular schedule of shipments will be in effect.

● **RESULTS OF PUBLIC OPINION SURVEY.** Results of the oil industry's new public opinion survey that has just been completed by Opinion Research Corporation, have been released.

The purpose of the survey was to determine and to appraise the attitude toward the oil industry during the current unbalance in supply and demand.

The survey sub-committee of the Oil Industry Information Committee summarized the public opinion survey for presentation to the full committee as follows:

"The fuel oil supply problem is worrying the public more than shortage of any other commodity. However, relatively few users claim to have suffered real hardship and the majority understand the causes of the pinch and the remedies for it approximately as the oil industry does, with one notable exception. The public attaches much more importance to exports than the industry does.

"The findings show also that the oil industry story about the supply situation has made quite a strong impression and that fuel oil users have to a considerable extent done the things they were asked to do to help. The misunderstanding about exports proves in a negative way the effectiveness of the industry's campaign. Practically nothing has been done to clear up public misunderstanding on that point, and the misunderstanding continues. As to the extent of use of oil, what the industry is doing to supply more, how the consumer can help, and other points on which the industry has gone all out in publicity the public understanding is for the most part all right. Few people favor turning the problem over to the government.

"Regarding possible gasoline shortage the public is skeptical, but a surprisingly high percentage (55) favors rationing if gasoline supplies do prove to be short.

"More than nine out of ten of the people interviewed said they had recently heard of shortages of fuel oil somewhere in the country. The only other shortage of which they were more conscious was that in housing. Four out of five had heard of fuel oil shortage in their own locality.

"When asked specifically about the effects of fuel oil shortage on them personally, 46 per cent of the fuel oil users said the shortage was serious. When polled on what the effects were, 32 per cent of fuel oil users said none, 22 per cent 'a little inconvenient', 31 per cent said 'inconvenient but no hardship,' and 14 per cent said 'real hardship.'

"On the question of 'who or what do you think is to blame for the fuel oil shortage,' 25 per cent of the public mentioned exports, 23 per cent increased use of oil, and 18 per cent lack of transportation facilities. Five per cent blamed politicians. But when asked directly if the oil companies were in any way to blame, 24 per cent said yes, 38 per cent said no, and 29 per cent had no opinion.

"Sixty-two per cent said the oil companies are supplying more fuel oil this year and only 11 per cent said 'less.'

"Spontaneous suggestions by the public to remedy the fuel oil shortages are: Limit exports, 25 per cent; improve transportation, 13 per cent; voluntary reduction in use, 12 per cent, and less than 10 per cent each for various other ideas such as use of substitutes, rationing (only 4 per cent), government intervention (4).

"Two-thirds of the public had heard of a possible lack of gasoline next summer, but only three in ten believed a shortage would actually develop. Of this group, 14 per cent said it would be because people would be driving more, 16 per cent thought it would be because there would be less gasoline than there was last summer, and the other 4 per cent had qualified explanations or none.

"When asked the question: 'Would you say that the present price of gasoline is high, about right, or low in comparison with the prices of other things you buy?' 47 per cent replied that the price was about right; 36 per cent said the price was high; 14 per cent had no opinion."

● **MEXICO SEEKS MORE OIL.** Mexico, pressed for dollars to buy industrial and agricultural equipment, is seeking to increase its production of oil. The success of President Miguel Aleman's 6-year self-sufficiency program hinges on that country's ability to build quickly a place for itself in world trade, according to reports emanating from Mexico City.

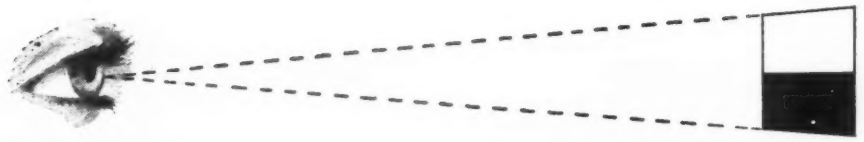
New fields are being sought in the Isthmus of Tehuantepec, Tabasco, Yucatan, Chiapas, Lower California, Chihuahua State, and Veracruz Valley. Cost of maintaining 40 drilling crews in the field will be 25,000,000 pesos ($5,000,000) a year and each well will average an additional 800,000 pesos ($160,000), it is estimated.

Without new wells, production by 1950 will be insufficient to meet national demand, and there would be no surplus for export, Pemex said in a report.

Jorge L. Cummins, head of the Pemex exploration department, estimated 1948 crude production at 53,700,000 bbl. Consumption in 1948 is expected to be 52,000,000 bbl, increasing to 70,000,000 bbl by 1955.

● **ERP OIL NEEDS.** A new survey made by the U. S. Department of the Interior asserts that an additional 50 Middle East wells and refining equipment would be sufficient to meet gasoline and fuel oil requirements of the European Recovery Plan. This assertion is based on the fact that the Middle East has 193 wells producing an average of 3971 bbl a day each, by far the highest average of any area covered in a study of all producing areas outside Soviet Russia.

● **GREATER TIDELANDS DRILLING PLANNED.** Spurred by the need for increased oil reserves, greater drilling activity in the Gulf Coast tidelands is in the offing. Several of the majors and some independents have announced new tests. Magnolia Petroleum Company plans two new wildcat tests off the coast of St. Mary and Terrebonne parishes, Louisiana. The Texas Company is making plans to drill a series of tests in the Gulf of Mexico about six miles southwest from High Island, Texas. Stanolind Oil and Gas Company has established a marine department and soon will begin drilling at four Gulf Coast locations. Rear Admiral Thomas E. Boyce, USN (Ret.) has been appointed marine superintendent. Other companies and individuals who are drilling in the tidelands or plan to do so include Humble Oil and Refining Company, Sun Oil Company, and Mike Benedum. The drilling platform of Humble, eight miles off Grande Isle, Louisiana, is said to be the largest ever constructed.



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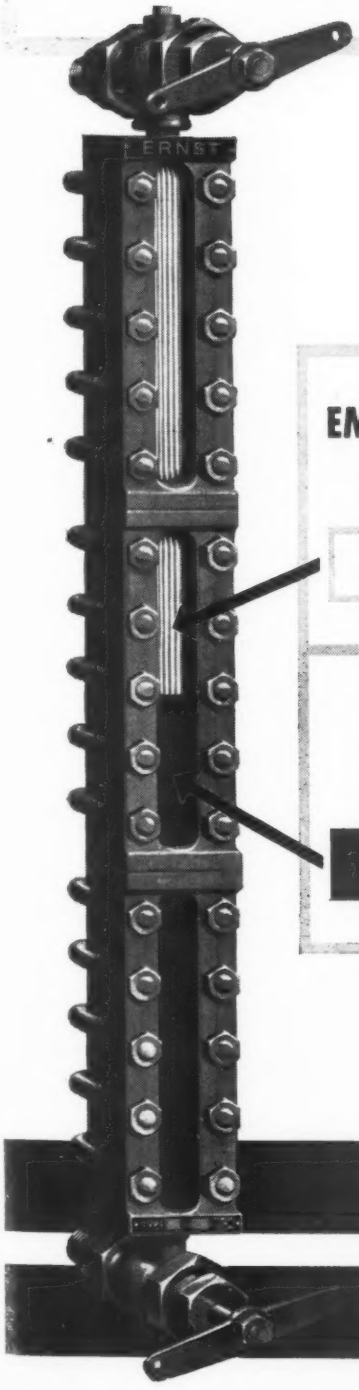
the PENBERTHY Reflex GAGE as far as you can distinguish between BLACK and WHITE



There can be no mistake in reading the Penberthy Reflex Gage. Due to the optical effect of the prismatically grooved glass, the liquid always shows black, and the empty space white. This optical effect is unvarying and absolutely sure. As a result, you can read the gage correctly as far as you can distinguish black and white . . . read it at a glance. There is no squinting to see the meniscus . . . the dividing line between liquid and empty space is always sharp and unmistakable.

In addition to standard units, Penberthy Reflex Gages are also fabricated to customer's specifications from special alloys to meet unusual corrosive and temperature conditions. They conform with API-ASME requirements.

PENBERTHY INJECTOR COMPANY

Established in 1886

Canadian Plant
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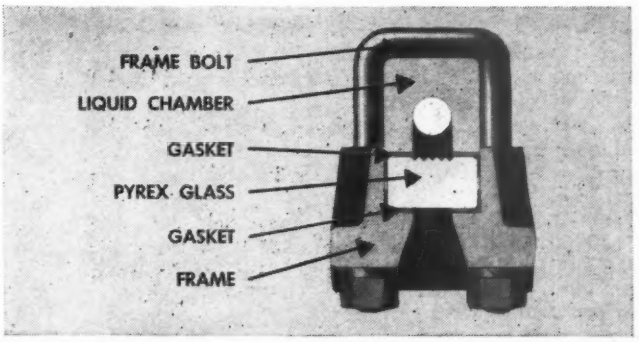

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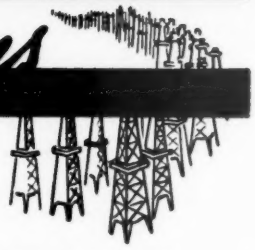

Exploration wells that have found production.

● **WYOMING.** Texas 1 Unit CNW NE 2-52n-72w, Adon dome, Campbell. 224 BOPD 31.5° Minnelusa 8997-9010 ft.

Seaboard and Resolute 53-33 NPRR, NW SW NE 33-58n-100w Silver Tip, Park. 500 BOPD 43.7° and 7000 MCF gas daily Phosphoria 8558 ft.

Pure 1 Unit NE SE 11-33n-84w West Poison Spider, Natrona. Oil shows 10,381-96 ft; 9175-245 ft; 13,814 ft, and 30-min DST gas 7192-98 ft.

Husky Ref 5 Unit NW NW SE 11-48n-102w Pitchfork, Park. Swb 230 BOPD 14° Madison 4355 ft.

Stanolind 2 Orchard SW NE SE 24-51n-93w Torchlight, Big Horn. Swb 70 B oil in 2-hr Madison 3362-3636 ft.

● **TEXAS.** Magnolia-Sinclair 1 R. W. Fair, Schofield sur, Lindale area, Smith. 90 B cond and 2000 MCF gas daily Rodessa 9512-82 ft.

Capital 1 E. J. Latham, sec 90 TE&L sur, Throckmorton. 420 BOPD Caddo 3915-29 ft.

Anderson-Prichard 1 Foster SW 12-15-H&TC sur, Sterling. DST 25 BOPH 4252-95 ft; 1470 B oil in 21 hr, 4252-332 ft.

Sunray 1 Marshall, Wm. Milican sur, A-201, Goliad. DST 220 ft cond Massive 8970-83 ft.

Paul B. Scott et al 1 Paul Riveire, T. G. Murphy sur, Cooke. 100 B 42° oil daily 1929-42 ft.

Woodley 1 Dickie, blk 938 TE&L, Throckmorton, 107 BOPD 41° Caddo 4178-90 ft.

Texas 1 Bernard, I. P. Rinehart sur, Blackfoot, Anderson. 163 BOPD 43.7° Rodessa 9035-60 ft.

Wilshire 1 McElroy Ranch Co., sec 148, ECCSD&RGNG sur, Upton. DST 2040 ft oil and 200 MCF gas from Pennsylvanian 7922-8004 ft.

Anderson-Prichard 1 Minnie S. Veal, tract 8, lge 114, Potter CSL sur, Cochran. 326 BOPD from 4995 ft.

Humble 1 Davison, sec 59, blk 1 HT&B sur, Fisher. 141.44 B 39.3° oil in 17 hr from 3160-78 ft.

Stanolind 1 Nix, sec 21, blk A-47 PSL sur, Andrews. DST 450 ft oil Ellenburger 11,484-499 ft.

R. R. Herrell et al 1 Jackson, sec 102, blk 8 H&GN sur, Pecos. 50-75 BOPD from 1790-832 ft.

Claud Hamill 1 Duncan, A. Edgar sur, Egypt field, Wharton. 99.5 BOPD 61°, 3085 MCF gas daily 6720-26 ft. New sand.

Deep Rock and Jennings 1 Ella Andrews 284-BBB&C Throckmorton. DST 490 ft oil from Marble Falls 4767 ft.

Texas Pacific Coal and Oil 62-D-A John F. Lane, McCamey field, Upton. 171.12 B oil in 12-hr Ellenburger 8070-130 ft. New sand.

J. H. Snowden et al 1 Gober 3-DI&C Throckmorton. DST 245 ft oil from Caddo 4469-85 ft. New sand.

Anderson-Prichard and Bay Pet. 1 Jones, 21-A7-PSL, Gaines. Swb 147 B oil in 48-hr Glorietta 6105-40 ft.

Phillips 1 Rudd, McMillan sur, Harrison. 113 B 39° oil in 16-hr Pettit 5624-45 ft.

Pure A-17 Cowden, 24-A52-PSL, Dollarhide, Andrews. 1800 BOPD 43° Silurian 8500 ft. New sand.

Cities Service 1 Schlittler, sec 1648, TE&L sur, Throckmorton. 282 B 41.6° oil in 8 hr Caddo 3758-64 ft.

Gulf 1 Lesikar, Kuykendall lge, Austin. 44 BOPD 38° from Wilcox Sand 9612-18 ft.

Gulf 3-A Jackson, Fannett dome, Jefferson. 73.6 B 47° cond from 11,045-053 ft. New sand.

L. T. Burns & Son 1 W. C. Jones, blk 1840, TE&L sur, Archer. 100.24 BOPD 41° Strawn 3211-23 ft.

Sohio 1 Irl Faver, sec 50, blk 21 T&P sur, Nolan. 183.12 BOPD 43° Ellenburger 6126-93 ft.

Humble 1 Rhodes, Joshua Grace sur, Woods. 277.38 BOPD 20.7° Eagleford 4216-27 ft.

Pan American 1 Clark, nw of Stamford, Haskell. 44 BOPD 36.6° King 2350-59 ft.

Magnolia 1 H&J 3, sec 2, blk A-6, PSL, Jones Ranch, Gaines. 397 B oil in 6 hr from Devonian 11,360-72 ft. New sand.

Wichita River and Phillips 1 Edwards, e of Henrietta, Clay. 169 BOPD from Strawn 4099-107 ft.

F. M. Manning 3-F Parrott, 968-TE&L, Throckmorton. 115 BOPD 40° Strawn from 2537-550 ft.

Sinclair Prairie and Texas 1 Mays Morton NE NW SE 30-4-2w, Garvin. DST 15 BOPH 58° and 3880 MCF gas daily Bromide 7392-424 ft.

Texas 1 Cameron County et al, Espiritu Santo grant, Cameron. Heavy gas show from about 8035 ft.

Humble 1 Thompson Bros. Mineral Corp, Chambliss sur, Trinity. DST gas and 110 ft cond from 10,595-632 ft.

Gulf 21-T-B Connell, 26-B-16-PSL, Jordan-Ellenburger field, Ector. 817 BOPD 42.2° Tubb 5270 ft.

Akin & Dimock 1 Mrs. J. J. Turbeville, 125-J. Richards-A368, Archer. DST 180 ft oil from 3799-817 ft.

Humble 1 S. Mayes Gas Unit I, 2-mi. s of S. Mayes field, Chambers. 134 B cond, and 1344 MCF gas daily from Lower Frio 12,021-26 ft.

Continental 1-E Albert West, sur 166, A. West field, Live Oak. 17,500 MCF gas daily Massive Wilcox 7256-66 ft.

A. D. Roberts 1 Mack Henry, S. Ingram sur, Brown. 132 BOPD 44° Caddo 2055-72 ft.

B. F. Phillips 1 Cunningham & Lawson, blk 138 University Lands, Callahan. 3500 MCF gas daily Flippen 562-71 ft.

● **WEST VIRGINIA.** Columbian Carbon 996 H. A. Gerlach, Mason. 39 MCF gas daily from 3193-586 ft.

● **OKLAHOMA.** Cities Service 1 Ramsey CSW NE 22-5n-4w, N. Lindsay, McClain. 2¼-hr DST 111 B oil Second Bromide 11,039-71 ft. New sand.

Tide Water et al 1 S. Marlow Unit CSE SW 27-2n-7w Stephens. DST cond and 1030 MCF gas daily 8290 ft.

Texas 2 T. Lindsay CNW SE 6-4-3w Garvin. DST 14 BOPH 70° and 2184 MCF gas daily from 9959-78 ft.

Continental 1 Dyer CNW SW 31-2n-7w S. Marlow, Stephens. 116 BOPD 32.6° and 250 MCF gas daily 8055 ft. New sand.

Carter 1 Kleme-Lacy CNE NW 5-4n-3w E. Lindsay, Garvin. 80 BOPH and 1740 MCF gas daily 9650-700 ft. New sand.

Falcon Seaboard and L. W. Barrett 1 Bierman NE NW NE 30-13n-53 Lincoln. 25-min DST 450 ft oil Wilcox 4991-5001 ft.

Mid-Continent 1 Parks SW SE SW 3-1s-5w Stephens. 75 BOPD Dronick Hills 7035-70 ft.

J. F. Smith 1 Morrow Unit CNE NE 18-9n-2w, Cleveland. 1-hr DST 400 ft oil Hunton 7265-350 ft.

Don T. Ingling 1 Miller SE SE NW 1-18-2w McPherson. Swb 25 BOPH in 6-hr Mississippian chat 2851 ft.

Jackson 1 McFadden SW SW SW 26-12n-10e Okfuskee. 60 BOPD 38° Cromwell 3128-51 ft.

Sohio 1-A Wilfong NW NE SE 34-5n-5e. Pontotoc. 98 BOPD 39° Viola 2910-44 ft.

● **KANSAS.** Shelburne and Farmer, Inc., 1 Madden-D NE NW NW 26-15s-18w, abd Madden field, Ellis. 75 BOPD Lansing 3275 ft. New sand.

● **MONTANA.** Stanolind 1 L. B. Zaerr NE NE SE 29-9s-23e nw Elk Basin, Carbon. DST spray and 390 ft 33° oil and 160 MCF gas from 6065-6100 ft. New sand.

● **WEST VIRGINIA.** R. Jackson well in Ritchie county. 18000 MCF gas daily.

● **NEW MEXICO.** Shell 1 Taylor-Glenn, lot 11, 3-21s-37e. 163 B cond and 4120 MCF gas daily from 8598 ft.

Magnolia 1-A Santa Fe SE SE 30-9s-36e Lea. 16 BOPD from 4873 ft.

● **LOUISIANA.** California 12 E. P. Brady 1-16s-23e S. Barataria, Jefferson. 142 B 52° cond 9683-703 ft. New sand.

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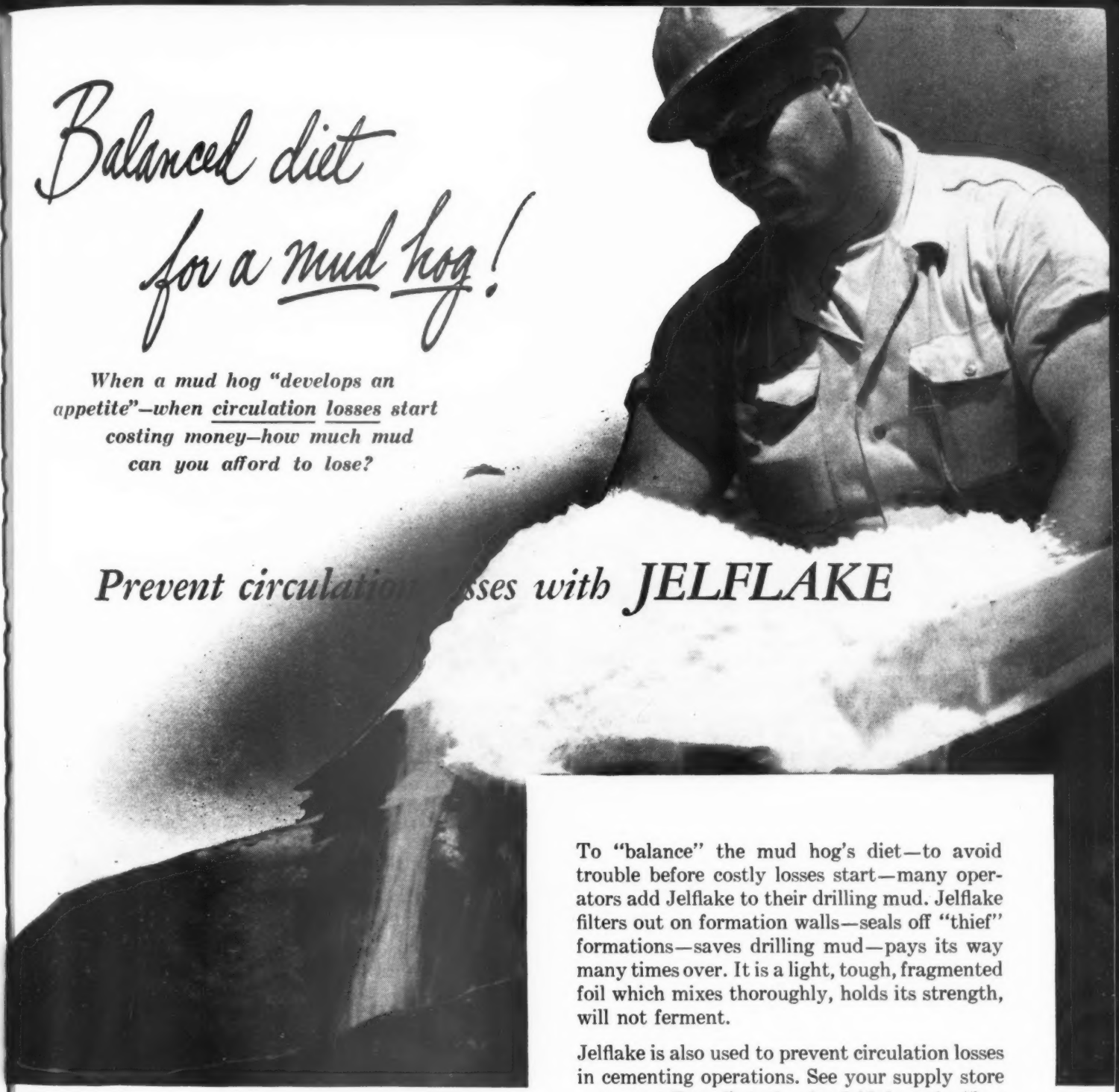

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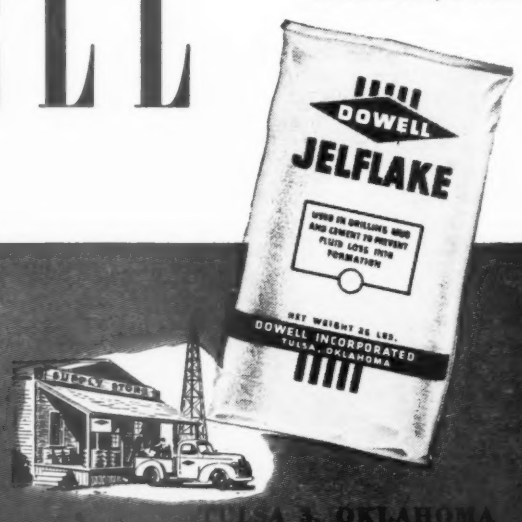

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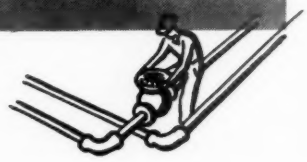


● **PANHANDLE EASTERN PLANS MOVE AHEAD.** The Federal Power Commission has issued a conditional permit to Panhandle Eastern Pipe Line Company to construct the portion of its natural gas pipe line project designated as the "Group C" facilities.

Construction of the Group C facilities is the third step in Panhandle's long range program as outlined in its application requesting authorization for the Groups A and B facilities. The Group C facilities include additional compressor powering and pipe line construction in the producing areas, substantial increases in compressor capacity on the main transmission line, and construction of about 356 miles of 26-in. line as looping on the main transmission line. Cost has been estimated at $27,021,000. The project is expected to be completed sometime in 1950.

Completion of the Group C facilities in addition to the Groups A and B facilities previously authorized will give Panhandle two interconnected looped lines from its Liberal Station in Kansas to Detroit, Michigan, with segments of a third loop line, and will increase the daily sales capacity of the system to an average of 575,000,000 cu ft during the summer months and 610,000,000 cu ft during the winter months.

● **ADDITIONS TO GAS SYSTEM PROPOSED.** Kansas-Nebraska Natural Gas Company, Inc., has plans to construct additions to its natural gas system. Facilities proposed for construction include partial looping of the company's Scott City-Stockton-Phillipsburg and Otis-Plainville lines in Kansas, and the replacement of an existing line between Holdredge and Elm Creek with larger diameter pipe and construction of 35 miles of new pipe line north of Elm Creek in the state of Nebraska. Installation of an additional 1000-hp compressor unit at the company's Deerfield, Kansas, compressor station and the construction of lateral lines and town border stations for service to additional towns in Kansas and Nebraska are also planned. Cost of the project has been estimated at about $3,130,865.

● **PLAN NEW FACILITIES FOR OHIO LINE.** The Ohio Fuel Gas Company, Columbus, Ohio, plans to build facilities for increased natural gas transmission capacity to the Marion and Lima, Ohio, markets. Estimated capital cost of construction is $2,986,250.

Facilities requested include about 97 miles of 20, 16 and 12¾-in. pipe lines extending from Ohio Fuel's Treat compressor station to a connection with the facilities of the West Ohio Gas Company at Lima, Ohio. Ohio Fuel would subsequently remove a 525-hp compressor station and about 118 miles of existing transmission lines ranging in size from 8⅝ to 16-in.

The application stated that pipe for the 12¾-in. and the 16-in. sections of the line would be available early in 1948 and that construction was expected to begin in May. The 20-in. pipe is scheduled for delivery in July and the company anticipates that all major construction would be completed by December 1, 1948.

● **EXTRA BIG PIPE LINES IN PROSPECT.** There are prospects of both New York and Chicago having new pipe lines from the Southwest gas fields. The new Trans-Continental Gas Pipe Line Company, Inc., was given a second chance for a line to New York when the Federal Power Commission ordered a reopening of the proceeding to permit the company to introduce certain additional evidence in support of its application. At the same time the Commission denied the motion of Texas Eastern Transmission Corporation, owner of the Big and Little Big Inch lines, to dismiss the application of Trans-Continental.

The Commission found that Trans-Continental had not demonstrated that it has sufficient natural gas supply for 15 years for the transmission pipe line from Texas to the eastern seaboard area. The Commission directed, however, that the record remain open for a period of six months to enable the company to present further evidence.

Texas Eastern, in the meantime, proposes to construct an extra 26-in. line along the right of way of the Big Inch. The principal obstacle to this and other expansion of the transmission concern is the contract under which the lines were purchased from War Assets Administration. The contract requires approval of the Secretary of Defense under certain conditions because of the possible need to convert the lines from gas to oil again for security reasons.

The Chicago area may get a third pipe line from the Southwest, it is indicated by the annual report of Peoples Gas Light and Coke Company. James F. Oates, Jr., chairman of the company, explained that a new pipe line, contemplated by People's Gas and Natural Gas Pipeline Company, is somewhat dependent upon the development of a process for liquefying natural gas to permit economical storage of gas supply.

Natural Gas Pipeline Company expects to complete the second large diameter line from Texas to Joliet by the end of 1948 and have it in operation at full capacity.

The third line would depend upon gas supplies and steel supplies. The success of the liquefaction of natural gas would be important, also, as there is no abandoned field near the Chicago area where gas can be stored for high seasonal loads. Oates estimated the line would cost from $75,000,000 to $100,000,000.

● **MANY ADD STORAGE FACILITIES.** New terminals and increased storage facilities are being built by oil companies.

Gulf Oil Company will erect terminal and bulk plants for oil storage, with total capacity in excess of 159,000,000 gal, to improve its oil supply system in the eastern half of the nation, according to a company announcement.

Tanks of 420,000 gal capacity and up will be built in 30 cities in 14 states, chiefly as additions to existing storage plants. Gulf said that construction has begun on most of these installations; several are being placed in operation; and all will be completed by the end of next year. In addition, many smaller tanks will be installed to supplement the major facilities.

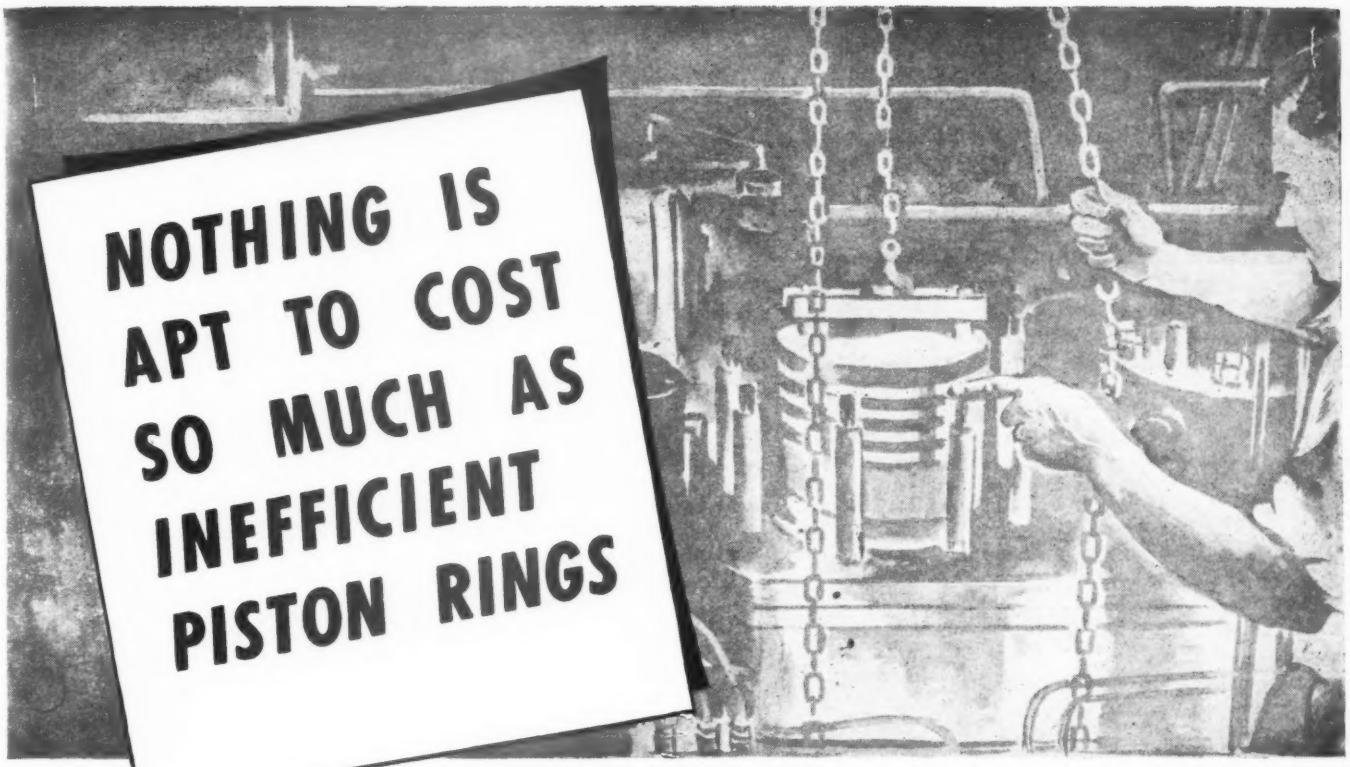
Phillips Petroleum Company has awarded contracts for engineering plans and supervision and the general contract for construction of a marine terminal on the east bank of the Mississippi River to consist of docking facilities for river barges, loading and unloading equipment for handling petroleum products. The structure will consist of five steel sheet piling mooring piers, each 20 ft in diameter, extending above the maximum high water line.

A construction and repair program to modernize Port Socony on Staten Island, New York, is to be undertaken by the Socony-Vacuum Oil Company, Inc. One of the effects of the modernization will be to enable Port Socony to handle new large-type tankers, which are under construction. The company announced recently that seven of the new tankers have been ordered. Each will have a capacity of approximately 8,400,000 gal.

The company also will build additional storage capacity for 61,000,000 gal of petroleum products before October in more than 25 cities in New York state and other parts of northeastern United States. The company said the move is being made to provide improved supplies of home-heating fuel for next winter. Socony-Vacuum also has a $45,000,000 refinery expansion program in work.

Allied Oil Company, Inc., increased storage capacity at all of its marine terminals and completed a new industrial fuel oil terminal on the Ohio at Follansbee, West Virginia. Allied said that it will place an additional tanker in operation in the Great Lakes this season and by the middle of the year, will take delivery of 10 additional fuel oil barges, which will be used to bring more oil up the Mississippi for delivery to industrial plants in Ohio and Pennsylvania.

The company said it will continue to expand transportation and terminal facilities to make more fuel oil available for industry in Ohio, Pennsylvania, Indiana and Illinois.



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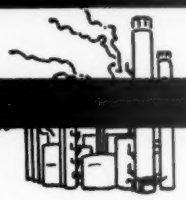


● **NEW ASPHALT PLANT IN AUSTRALIA.** Early in April the first cargo of crude for Australia expected to leave Bahrein Island in the Persian Gulf, to make possible the actual start of operations of the new asphalt plant in Sydney, Australia, which is being constructed for Bitumen and Oil Refineries (Australia) Ltd., (Boral).

Sixty per cent of the issued capital of 1,250,000 Australian pounds ($4,012,500), is widely distributed among the Australian public. The balance is held by Caltex, which will supply crude charging stocks from its oil resources in the Middle East. Construction is being supervised by Caltex engineers on loan to Boral. The refinery manager, Alden J. Herron, is an American with almost 23 years refinery experience with Caltex affiliates in Texas and the Middle East.

The largest storage tanks in the Southern Hemisphere, with a capacity of 5,000,000 gal, were constructed by butt welding. The usual method used in Australia has been lap welding.

The asphalt plant is on a 47-acre site adjacent to Bunnerong Power Station, and is convenient to road and rail facilities and to Botany Bay, the discharging point for tankers bringing the crude oil to the refinery. Plant facilities will include distillation equipment, vacuum reduction equipment for reducing the crude charge to desired viscosity, air-blowing equipment to secure the desired ductility and to further assist in reaching the desired viscosity.

This will be the first asphalt plant in Australia. It will manufacture a complete line of asphaltic products including road paving asphalts, roofing and industrial grades. Australia, which up to now has been dependent on overseas supplies of asphalt for her roads and industries, will soon have a home source producing at least 50,000 tons annually. The plant is expected to be in operation by June.

● **CUSHING REFINERY ENLARGED.** The Refinery Engineering Company of Tulsa and Chicago will supervise new construction scheduled to increase capacity of refinery and cracking units of the Midland Cooperative Wholesale Company's Cushing, Oklahoma, refinery, according to an announcement by T. M. Lumly, Jr., president of The Refinery Engineering Company.

Approximately $500,000 is to be spent, most of which has been allocated for the addition to the refinery and cracking plant. Walter Switzer has been named resident construction head of the project. When completed the expanded plant will have a capacity stepped up from its present 4200 bbl to 6500 bbl per day. Cracking plant facilities will have been enlarged 25 per cent to make possible the processing of 2000 bbl of charging stock per day.

● **WORK BEGUN ON SHELL CHEMICAL UNIT.** Construction is under way on a new Shell Chemical Corporation plant at Martinez, California, to manufacture "petroleum additives," it was announced by J. Oostermeyer, president of the company. Petroleum additives, Oostermeyer explained, are chemicals that are added to lubricating oils and other petroleum products to increase their life and performance.

Production equipment will be constructed of special materials to help guard product quality during all stages of manufacture. Ralph M. Parsons Company is the contractor for engineering and construction of the additives plant. It is scheduled for completion late this year.

● **SUN BEGINS GASOLINE PLANT.** The Sun Oil Company will build and operate facilities to conserve natural gas from oil producing wells in four fields in Starr County, Texas. The project, involving construction of a natural gasoline plant equipped to process 25,000,000 cu ft of gas a day, is part of Sun's $12,000,000 natural gas conservation program.

The plant is designed to recover 80 per cent of the propane and substantially all the butane and natural gasoline from the casinghead gas produced in the Sun, North Sun, North Rincon and Garcia fields.

James E. Pew, manager of the company's natural gas and natural gasoline division, said clearing of a 40-acre plant site has begun. Specifications for the plant have been forwarded to contractors with requests for bids. It is hoped the plant will be in full operation by April 1, 1949.

Ten other oil companies operate in the fields which the new plant will serve. The plant has sufficient capacity to process the natural gas production of these companies as well as Sun's. All will be given an opportunity to utilize the services of the plant.

● **OFFERS NEW LUBRICANT.** The Texas Company announced an entirely new type of roller bearing lubricant designed to replace the liquid oils on locomotive, passenger and freight car journals.

The new product, The Texas Company officials said, will increase time between periodical inspections, and will eliminate necessity of station platform journal inspections of freight car journals and boxes. It is believed that the new lubricant can remain in service for two years or more before repacking becomes necessary.

● **PRODUCES ODORLESS SOLVENT.** Especially suitable for dry-cleaning of clothes and other textile products, a new and relatively odorless solvent designated temporarily as "PD942A" was announced by the Socony-Vacuum Oil Company, Inc. It practically eliminates the time needed for deodorization.

Also, according to Socony-Vacuum, the product is unchanged by redistillation or filtration, and where it is used exclusively in dry-cleaning establishments, the risk of garments re-absorbing shop odors is eliminated.

● **SINCLAIR COMPLETES CRACKING UNIT.** Installation of a new catalytic cracking unit at Marcus Hook, Pennsylvania, has been completed by Sinclair Refining Company. The new daily maximum production is 15,000 bbl of gasoline and a maximum of 6000 bbl of heating oil.

The company has also acquired additional land near the new unit to provide space for construction of storage tanks with a 750,000-barrel capacity.

The cracking plant has daily capacity of 25,000 bbl of charging stock, which makes high octane motor gasoline, heating oil, and thermal cracking stock and gas.

● **TEXAS CITY PLANT REBUILT.** The first unit of the reconstructed Monsanto Chemical company in Texas City has begun operations again, Edgar M. Queeny, chairman of the board, announced.

The plant, destroyed last April when the S. S. Grandcamp exploded in the Texas City harbor, will produce styrene, an ingredient used in making plastics. Queeny said that the insurance claim for the plant would be $22,000,000, the largest claim in the history of the company.

● **ILLINOIS REFINERY ADDS UNITS.** Additions to The Texas Company's refinery at Lawrenceville, Illinois, which will increase the plant's capacity were announced by H. S. McCray, superintendent. The new construction includes a new crude and vacuum distillation unit, fluid catalytic cracking and auxiliary equipment. Modernization of the plant contemplates the processing of a wide variety of crude oils.

"The enlargement and modernization program at Lawrenceville is an important part of The Texas Company's nationwide post-war expansion program, which should go far toward meeting the unprecedented demand for petroleum products," said McCray. It is expected that most of the new equipment will be situated near the present cracking units. Several months will be required to design and purchase equipment. Meanwhile, work of clearing sites for the new units will continue.

THE Petroleum Engineer
APRIL, 1948

Summing up the global oil situation

By H. J. STRUTH, *Editor*, The Petroleum Data Book

EXCLUSIVE

We have heard a great deal lately about an oil shortage in the United States. We have read alarming reports purporting to show that we are running out of oil and that we not only face a serious shortage of fuel oil next winter but face also the prospect of a gasoline shortage this summer. I, for one, cannot go along with the alarmists who seem to lack faith in our system of free enterprise. I have been in the oil business for more than 30 years and this shortage talk is not new to me. I have heard the shortage cry repeatedly over the last 30 years and I have seen predictions of famine drowned in several floods of oil!

I distinctly recall alarming statements made back in 1923 to the effect that the United States faced a serious oil shortage and that our nation would be out of oil in a matter of 10 years. At that time, it was estimated that U. S. oil reserves were 7,600,000,000 bbl. At then current production rates, the inference was made that our underground supply would be exhausted in 10 years. The same line of reasoning is being disseminated by alarmists today. Yet, over the last 25 years actual U. S. production of oil has exceeded 27,000,000,000 bbl and the nation's underground petroleum liquid reserves at the close of 1947 amounted to more than 24,000,000,000 bbl. In other words, following the "shortage" predictions of 1923 the industry produced and found more than 43,000,000,000 bbl of additional oil or about six times the quantity of reserves reported to be available 25 years ago! Can anyone say with any degree of certainty that we will be out of oil in the United States within the next 10 years—or 25 years?

True, we haven't in recent years discovered a Kettleman Hills, an Oklahoma City, an East Texas, or a Conroe field, with reserves of such major proportions. But, we are finding hundreds of new oil pools in the United States every year and their development over a period of from five to eight years following discovery continues to result in substantial upward revisions of initial reserves estimates. Of far-reaching importance in this connection is the fact that over the last eight years the quantity of reserves added by extensions and revisions has amounted to well over 13,000,000,000 bbl, or about 80 per cent of all the reserves found during this period. Another important consideration, and a factor of far-reaching significance in the nation's oil outlook, is the intense effort of the industry to find new sources of oil supply for future needs. Despite extremely high costs and by the incentive of higher crude prices, the industry is drilling twice as many exploratory wells as were drilled prior to and during World War II. Let's not overlook the fact that such record drilling operations are being pursued within the limits of the availability of equipment. Given an adequate supply of steel for the production of far more drilling equipment, the oil industry could drill many more wells, leading to the discovery of more reserves. There surely is no shortage of drilling locations. Millions of acres of prospective oil areas are under lease, awaiting drill tests.

Now let's look at the figures and see what started all this talk about an oil shortage. Analysis of the oil supply and demand situation for the United States in 1947 shows that we had a shortage. The consumption of petroleum and its products last year exceeded production by 14,000 bbl daily. Incidentally, this was the difference between our imports and our exports. We shipped out 14,000 bbl a day more than we received from other nations. We consumed our total output—5,449,000 bbl daily. The total deficiency, created by exports, amounting to 5,041,000 bbl for the year was taken from storage, leaving total above-ground year-end stocks of all oils at a total of 502,053,000 bbl. There is no intention here to minimize shortages in supply that were experienced in the Middle West and the North East during the recent severe winter period. Real shortages experienced by distillate fuel oil consumers were, however, not due to potential supply but were due primarily to lack of adequate tanker and tank car distribution facilities. The industry had the oil but could not move it fast enough or in time to prevent hardships suffered by some consumers.

The whole world was short of oil last year. The facts show there was a net shortage of 53,000 bbl a day in 1947. Supply of all oils in the world amounted to 8,668,000 bbl daily, whereas consumption totaled 8,721,000 bbl daily. We had to draw on our stored supplies to the

tune of 5,041,000 bbl; the rest of the world apparently reduced stocks by about 14,304,000 bbl. The world used 19,345,000 bbl more than was produced in 1947. These figures do not include unknown military consumption outside the United States and Great Britain. I did not get my Russian figures from Joe Stalin, but if the dope I got on production and my guess on consumption are anywhere near correct, it looks as if Joe was short of oil last year to the tune of about 50,000 bbl daily. He made up part of the deficiency by taking 37,000 bbl a day of his supply from Eastern Europe, 4000 bbl from Western Europe, and good old Uncle Sam gave him 2000 bbl a day during 1947. Russian military and industrial requirements comprise a major share of the supply accounted for, but it is obvious that additional, unknown military supplies are acquired by occupation forces in Europe, the Middle East, and the Far East. Yet, the combined supplies of Russia and Eastern Europe are less than 12 per cent of those available to the United States.

The Western Hemisphere and the Middle East are the mainstays of the world's oil supply. These areas last year had a combined surplus above domestic needs of 1,231,000 bbl daily. Europe, Russia, Oceania, and the Far East had a combined deficiency in supply exceeding domestic needs of 1,149,000 bbl daily. A significant fact is that the Western Hemisphere and the Middle East are the sources of 91 per cent of the world's oil production and contain about 84 per cent of the world's proved reserves. The "haves" and the "have-nots" are shown in Fig. 1. The surplus or shortage of major world areas represents the difference between production and domestic requirements. Summation of the world's balance sheet for 1947 (Table 1) shows that combined shortages, excluding military needs, aggregated 1,657,000 bbl daily. Surplus supplies, above domestic needs of Mexico, South America, Eastern Europe, and the Middle East aggregated 1,739,000 bbl daily. Europe and Russia had a combined deficiency in oil supply last year of 858,000 bbl daily.

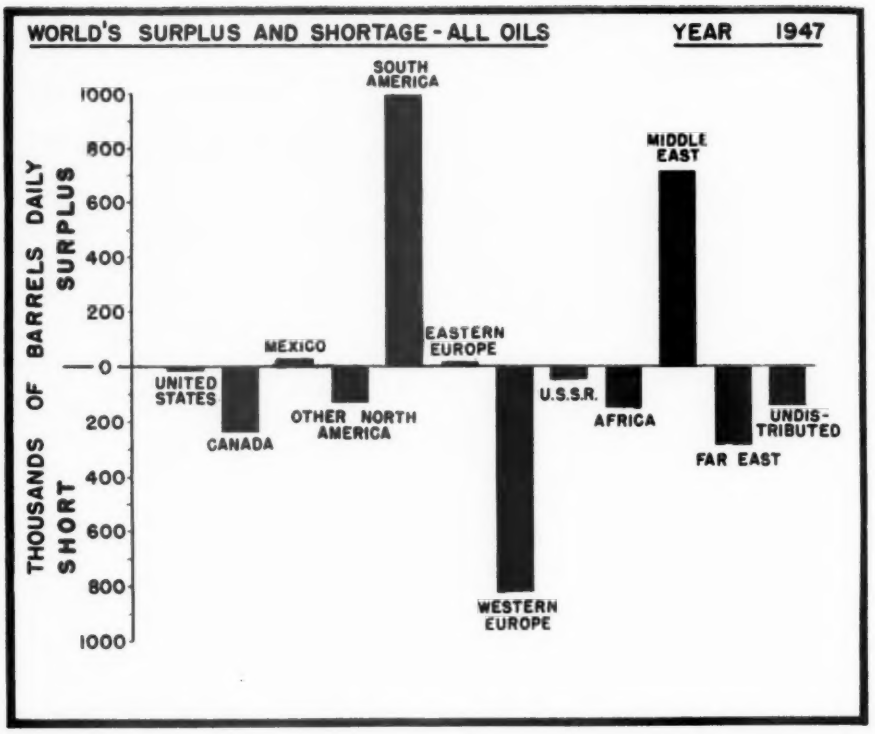


FIG. 1.

In a recent analysis of the oil shortage situation in the United States, I made the statement, advisedly, that extremely cold weather in the Northeast and Middle West, coupled with inadequate transportation facilities, brought a "run" on supplies of distillate fuel oils. Dealers absorbed all distillates available; home owners, apartment and commercial burner users filled their tanks. This created a demand far greater than actual consumptive requirements. It was like a run on a bank; there was enough money there, but it did not last long after the run started. The real trouble, however, was the inability of the industry to move its products into areas of critical shortages due to lack of tankers and tank cars.

The oil industry has been accused of being wasteful and inefficient. I challenge that statement because the facts support just the opposite viewpoint. The history of the oil industry has been one of continuing accomplishment. Tributes to its efficiency are the manifold achievements made in the face of apparently insurmountable obstacles. In the comparatively short span of 89 years it has contributed generously to the progress and welfare of every American and in substantial measure to the welfare of all

TABLE 1. Principal world oil movements, 1947.
(Thousands of barrels daily)

From	To												
	U. S.	Canada	Mexico	Other North America	South America	East Europe	West Europe	Russia	Africa	Middle East	Oceania and Far East	Undistributed* (military)	Total
United States	..	150	12	52	16	2	161	2	10	2	44	..	451
Canada	2	..	..	2	..	..	1	..	..	..	..	..	5
Mexico	27	1	..	4	..	..	4	..	..	..	..	..	36
South America	402	82	..	60	..	3	382	..	35	1	3	45	1013
Eastern Europe	..	..	..	..	..	..	..	37	..	..	..	..	37
Western Europe	..	..	..	..	..	3	..	4	..	..	..	..	7
Russia	..	..	..	..	..	3	3	..	..	..	..	..	6
Africa	..	..	..	..	..	..	..	..	..	..	..	..	..
Middle East	6	..	..	..	4	13	254	..	100	..	245	90	712
Oceania and Far East	..	..	..	..	..	..	1	..	..	..	..	..	1
Total imports	437	233	12	118	20	24	806	43	145	3	292	135	2268
Exports	451	5	36	0	1013	37	7	6	0	712	1	0	2268
Net movement (in—, out+)	+14	—228	+24	—118	+993	+13	—799	—37	—145	+709	—291	—135	0
Production	5449	21	154	1	1422	109	39	520	25	859	69	..	8668
Net new supply	5435	249	130	119	429	96	838	557	170	150	360	135	8668
Domestic consumption	5449	252	131	121	427	97	859	570	170	150	360	135	8721
Stock change	—14	— 3	— 1	— 2	+ 2	— 1	—21	—13	..	..	..	..	—53

*Incomplete—U. S. and Great Britain only.

TABLE 2. Condensed summary of important U. S. oil industry figures.
(Preliminary data)

(Annual data)	1938	1941	1945	1946	1947	1948 projected	Per cent increase		
							1947 vs 1938	1948 vs 1938	1948 vs 1947
Supply—all oils, thousand bbl per day	3,621	4,339	5,321	5,450	5,886	6,230	62.6	72.1	5.8
Demand—all oils, thousand bbl per day	3,646	4,369	5,358	5,331	5,900	6,210	61.8	70.3	5.3
Crude production, thousand bbl per day	3,327	3,842	4,695	4,751	5,085	5,400	52.8	62.3	6.2
Refinery runs, thousand bbl per day	3,191	3,861	4,711	4,740	5,075	5,450	59.0	70.8	7.4
Motor fuel production, thousand bbl per day	1,555	1,921	2,184	2,128	2,301	2,420	48.0	55.6	5.2
Motor fuel demand, thousand bbl per day	1,570	1,902	2,149	2,138	2,308	2,400	47.0	52.9	4.0
Fuel oil production (including transfers), thousand bbl per day	1,252	1,499	2,034	2,042	2,165	2,275	72.9	81.7	5.1
Fuel oil demand, thousand bbl per day	1,250	1,608	2,177	2,085	2,349	2,450	87.9	96.0	4.3
Distillate fuel oil demand, thousand bbl per day	402	519	711	745	900	975	123.9	142.5	8.3
Residual fuel oil demand, thousand bbl per day	848	1,089	1,466	1,340	1,449	1,475	70.9	73.9	1.8
Imports—all oils, thousand bbl per day	149	266	311	377	437	500	193.3	235.6	14.4
Exports—all oils, thousand bbl per day	531	298	501	419	451	425	—15.1	—20.0	— 5.8
Stocks all oils, million bbl	556	556	464	507	502	509	— 9.7	— 8.5	1.4
Refining capacity, thousand bbl per day	4,185	4,587	5,342	5,480	5,621	5,945	34.3	42.0	6.0
(Two months—January-February)									
Supply—all oils, million bbl	217	235	313	317	328	376	51.2	73.3	14.6
Demand—all oils, million bbl	198	240	331	316	353	383	78.3	93.4	8.5
Stocks—all oils, million bbl	583	560	459	464	483	495	—17.2	—15.1	2.5
Motor fuel supply, million bbl	89	101	130	118	126	142	41.6	59.6	12.7
Motor fuel demand, million bbl	74	91	118	109	116	124	56.8	67.6	6.9
Motor fuel stocks, million bbl	90	94	90	102	100	106	11.1	17.8	6.0
(Annual data)									
Average price of crude	$1.13	$1.14	$1.22	$1.41	$1.94	$2.61§	71.7	131.0	34.5
Total wells drilled*	26,712	29,070	24,833	27,412	31,026	34,000	16.2	27.3	9.6
Exploratory wells drilled†	5,765	5,022	8,187	9,403	10,643	12,000	84.6	108.2	12.8
Initial reserves discovered, million	1,854	980	1,535	1,558	1,860	..	00.3	..	..
Reserves discovered per exploratory well, thousands	445	525	196	173	185	..	—58.4	..	..
Initial finding cost per bbl	$0.139	$0.358	$0.557	$0.620	$0.590	..	324.5	..	..
Drilling cost per exploration well	$13,975	$23,730	$44,650	$44,700	$48,750	..	148.8	..	..
Proved oil reserves (millions)	15,507	19,024	20,453	19,942‡	20,874‡	21,488‡	34.6	38.6	2.9
Number producing wells, thousands	363	389	412	416	421	429	16.1	18.2	1.9
Reserves per well, thousands	42.7	48.9	49.6	48.0	49.5	50.0	15.9	17.1	1.0

*Excludes service wells. †Wildcat producers and all dry holes. ‡Crude oil only, January 1. §As of March 1, 1948.

nations. American oil played a decisive part in winning World Wars I and II. It created new products, including synthetic rubber, toluene, and 100-octane gasoline, without which our armed forces could not have won a decisive victory. It revamped, almost overnight, its productive and transportation facilities to a war footing, and then reconverted its facilities to meet the greatest peacetime demand for petroleum products in its history. It is now utilizing all its ingenuity and scientific know-how to meet future requirements for peace — and even for another war if necessary—and it is making marked progress in overcoming new obstacles that is nothing short of miraculous. Waste has not escaped the notice of the oil and gas industry and efforts in that direction have been highly successful. Efficiency in the oil industry sets a pace that might well be emulated by many other large industries.

We consumed all the oil we produced in 1947. We might have consumed somewhat more than we produced if transportation facilities had permitted additional movements from storage supply centers.

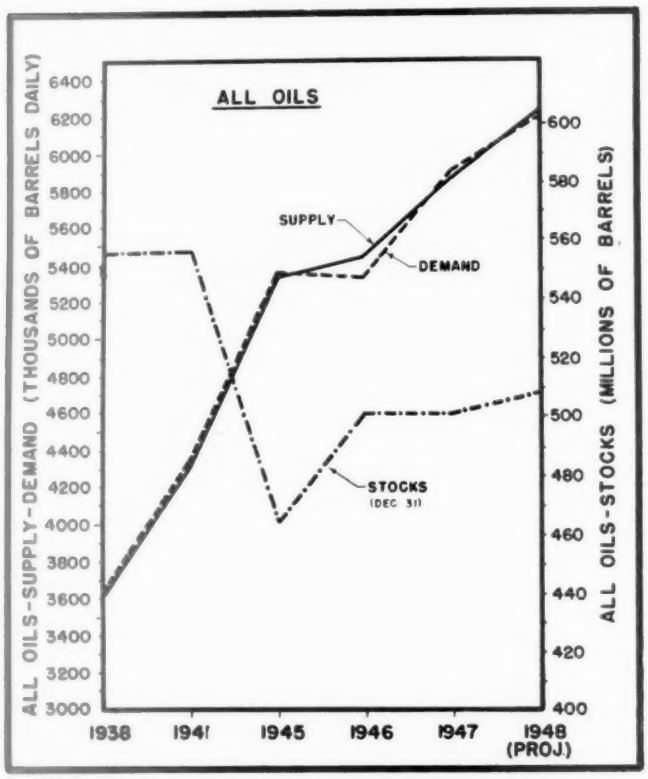
Projections of demand this year indicate a further increase of at least 5.3 per cent over the peak year of 1947. This means that the increase in demand over 1938 is 70 per cent. But, what those who cry "shortage" fail to consider is that our supply increase is in the order of 72 per cent. The shortage philosophy ignores the industry's alertness to the need for greater supplies and expansion of facilities for the conversion to products and their movement to consuming centers. The important point is that the oil industry is doing something about it, but is so busy doing it that it forgets to tell the pubilc what a wonderful job it has done and is doing to maintain a continuous and unfailing supply of oil not only today but for many years to come. The oil industry is a going concern, managed by the best industrial brains in the world. If you want a sound example of the workings of free enterprise and why it works best for the public interest, look at the oil industry's record! Show me any other system that would encourage a wildcatter to risk a million dollars, like Mike Benedum in West Texas, to find a new oil field!

Let's look at what the oil industry has done to meet the constantly growing demand for its products. (Table 2.) Of paramount importance in this connection is the record of what was accomplished in the first two months of this year. Since January 1, 1948, the demand for all oils was 30,000,000 bbl greater than in the same period of last year. The increase in demand was 8.5 per cent above last year. Prognosticators who read about the demand outlook, but do not have or want the figures that show the supply situation, say the industry cannot meet any further increase in demand. The facts show, however, that the supply of all oils in the first two

TABLE 3. Trends of industrial activity and oil consuming units related to demand for petroleum and its products.
(Annual data)

	Federal Reserve Board index of industrial production (1935-39=100)	Domestic demand all oils (mill bbl)	United States motor vehicles registered (mill)	Domestic gasoline demand (mill bbl)	Farm tractors in use (thous)	Domestic kerosine demand (mill bbl)	Domestic oil burners in use (thous)	Domestic distillate fuel oil demand (mill bbl)	Commercial and industrial oil burners in use (thous)	Domestic residual fuel oil demand (thous)	Domestic lube oil demand (mill bbl)
1938	89	1137	29.4	523	1368	56	1531	117	210	292	21
1939	109	1231	30.6	556	1447	61	1668	135	223	323	24
1940	125	1327	32.0	589	1545	69	1862	161	238	340	25
1941	162	1486	34.5	668	1664	69	2135	173	256	383	30
1942	199	1450	32.6	589	1884	70	2402	186	288	406	29
1943	239	1521	30.5	568	1919	69	2386	208	293	467	31
1944	235	1671	30.1	632	1953	72	2375	209	285	512	32
1945	203	1773	30.6	696	2072*	76	2392	226	321	523	35
1946	170	1793	33.9	735	2777*	89	2526	243	345	480	35
1947	187	1989	37.2	795	3000Ⓔ	103	2937	298	384	518	37

*July 1. Ⓔ–Estimated.



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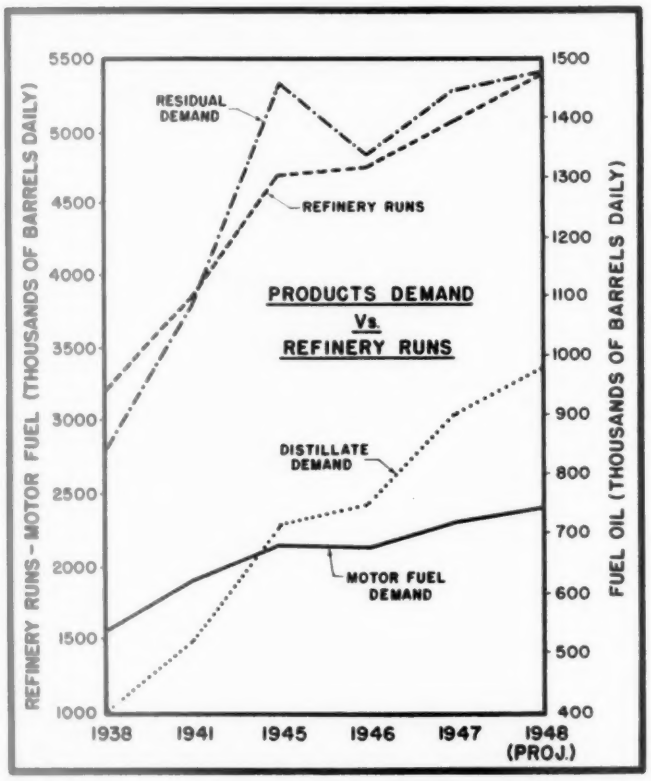

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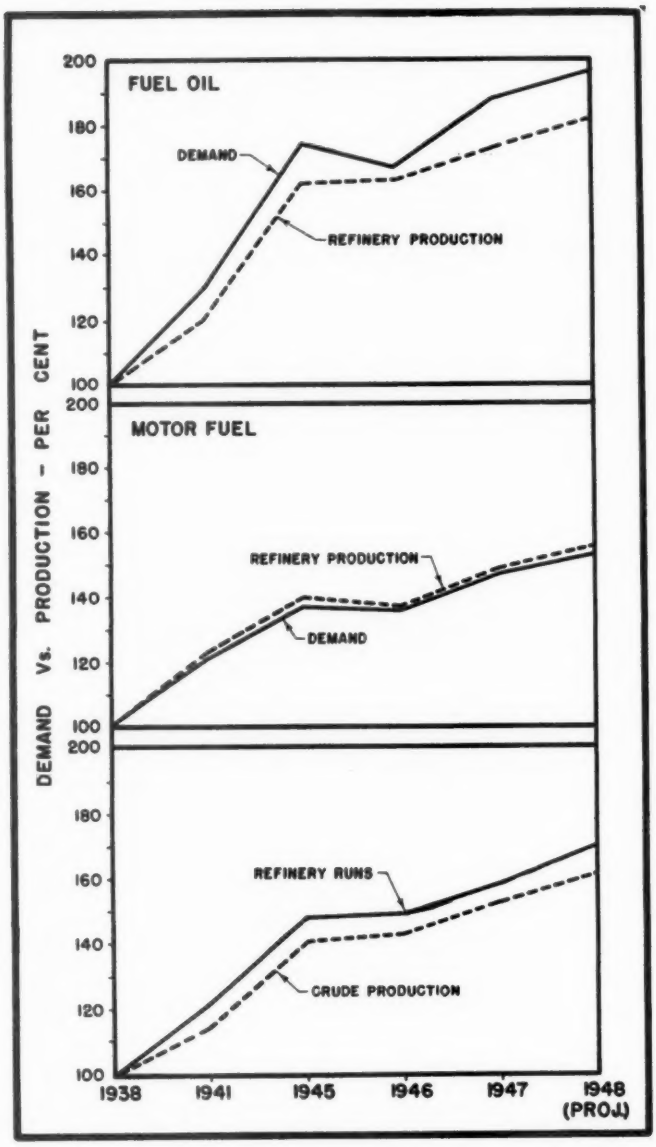


FIG. 3.

months of this year was increased 48,000,000 bbl over the same period of last year. Supply was 15 per cent greater, against an increase of 8 per cent in demand. Furthermore, stocks of all oils were 495,000,000 bbl on March 1, against 483,000,000 bbl a year ago. This is the highest February stock level since 1941. It is 31,000,000 bbl above the February, 1946 level; 12,000,000 bbl above last year. The annual record and the projections indicated for 1948 (Fig. 2) present an impressive picture of the industry's successful efforts to keep supply abreast of demand. In fact, indications this year point to the likelihood that supply may exceed demand by at least 20,000 bbl daily. Stocks of all oils this year are expected to increase nearly 7,000,000 bbl over the 1947 level.

The public has been told only recently that the supply of gasoline may be inadequate this summer and that it may even be necessary to ration available supplies. The motoring public (perhaps I should say the "muttering" public) believes this means an end to planned vacation trips and wonders whether to sell that new car now while prices are still high. The facts indicate the advisability of keeping the family car and planning the summer vacation trip as usual. Unless we have another war (God forbid!), there should not be a gasoline shortage this summer. In the next war there will not be any gasoline for civilians. In fact, there may not be any civilians left to consume gasoline after the next war! Sound international diplomacy and an intelligently planned, well executed program of world peace among all nations could prevent another war. War brings

regimentation of industry and the next one may bring an untimely end to our highly successful system of free enterprise.

Demand for gasoline in the first two months of this year was 8,000,000 bbl greater than in the same period of last year. But the supply was greater than last year by 16,000,000 bbl. March 1, 1948, motor fuel stocks were the largest on record for this season, and were 6,000,000 bbl above a year ago.

Expansion of refining facilities, backed by a steady increase in crude oil production, has effected an abnormal pre-seasonal stock build-up. Still runs are 16 per cent above last year, gasoline output is 12 per cent greater, and gasoline stocks are 6 per cent higher than last year. The annual figures and projections for 1948 (Fig. 3) show why there is little to support the gasoline shortage predictions. The extent to which the industry has maintained refining operations in conformity with demand for motor fuel is shown by the increase of 55 per cent in production, against an increase of 53 per cent in demand.

With refinery runs this year expected to average about 5,450,000 bbl daily and with yields adjusted in conformity with seasonal requirements of gasoline and distillate fuels, the supply of gasoline available from crude oil processed and natural gasoline blends will be substantially greater than the expected demand for gasoline this year of 2,400,000 bbl daily. Imports have not been considered here, but they offer an additional supply from the Caribbean area this year.

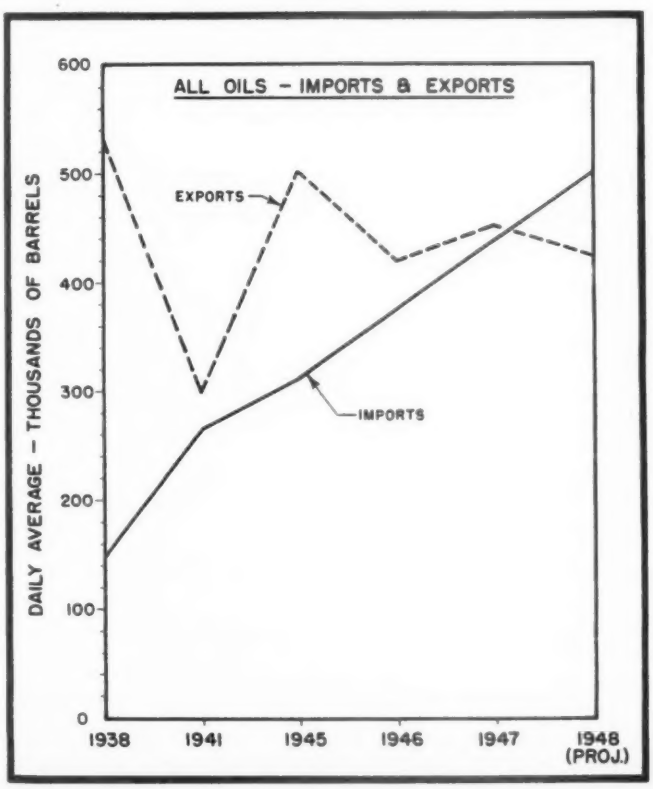
The heavy distillate consuming season has ended and refiners will now concentrate greater effort to the production of motor fuel and the building of adequate stocks for summer demand peaks. Yet, the industry fully recognizes the need for a stock building program for distillate fuel oils, in order to prevent spot shortages next winter that were experienced this winter in critical consuming areas. Easement in the tanker situation has lately been reported and will no doubt enable the industry to move more distillate fuel oils into the Northeastern area in late summer and early fall. This may reasonably be expected to alleviate spot shortage conditions recently experienced. Increased refining capacity in the Middle West, with preseason shipments and stock-piling in that area may also prevent spot shortages of distillate fuel oils there next winter. A mild winter in 1948-49 may even create a surplus in local supplies, but that is one of the many risks the oil industry takes to satisfy consumer demands. Projections of refining operations for 1948 (Fig. 4) indicate a further substantial increase in still runs over last year. Daily runs are expected to average this year about 5,450,000 bbl daily, against an average last year of 5,075,000 bbl daily. This trend is in close correlation with demand trends anticipated this year for the principal refined products.

The trend of imports is definitely upward, while the outlook for exports points to a recession from the levels of recent years. (Fig. 5.) From now on the United States is destined to become a net importer of petroleum and its products. This has not happened since 1922, when Mexican imports exceeded our total exports to foreign nations.

Indications this year point to the likelihood that imports of all oils will exceed exports by at least 75,000 bbl daily. We will probably import a half-million barrels a day this year and the trend is definitely toward greater imports over succeeding years. By 1951, I believe our imports will exceed exports by as much as 600,000 bbl daily. We will export less oil because more and more of the foreign demand will be met by supplies made available in the Middle East. This is a decidedly favorable economic turn of events for the United States because our immediate and future requirements call for more supply for domestic and military needs. Imports and the discovery of large reserves of oil are no longer a threat to the economic stability of the American petroleum industry.

Higher crude oil prices have had a pronounced effect upon drilling activities and consequent rates of new field discoveries. (Fig. 6.) Price advances granted in 1947 spurred exploratory drilling to the highest level in the industry's history. Development wells drilled last year were the greatest since the 1920's. Initial reserves discoveries, amounting to about 1,860,000,000 bbl, were substantially above the annual averages during the period 1935-46. Today, the average price of crude oil in the United States is about $2.61 per bbl. This price is expected to provide the added stimulus to greater exploration effort than ever before; however, with steel supplies still far short of the industry's needs, this year's record will not attain the maximum results that might

FIG. 5.



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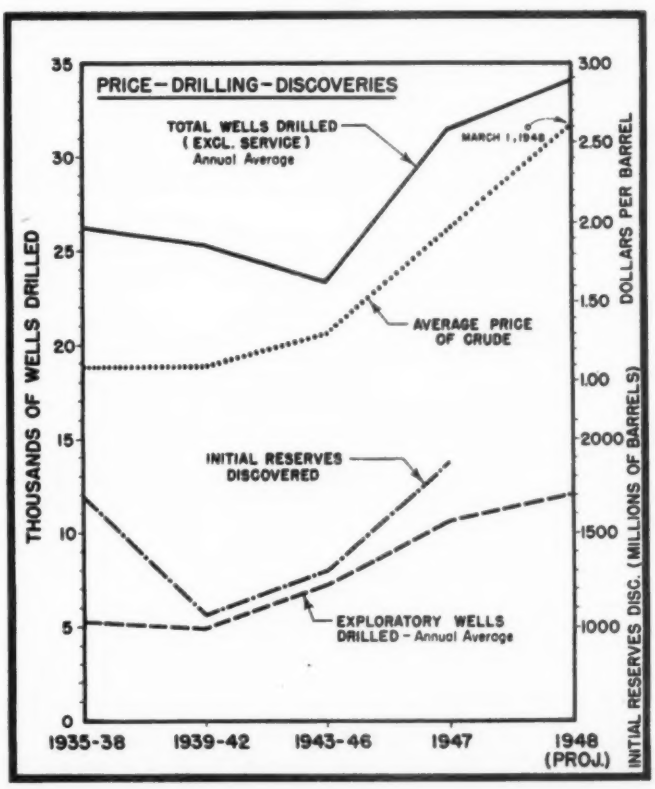

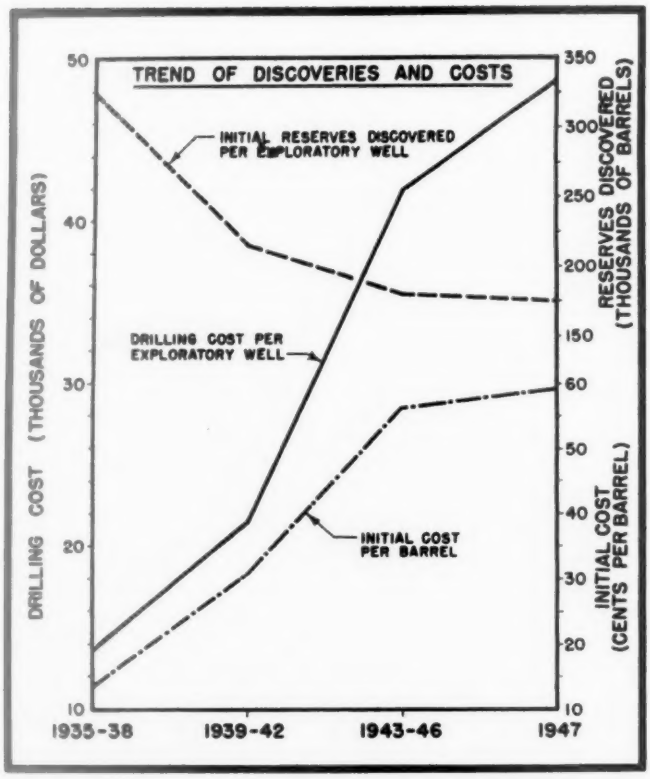

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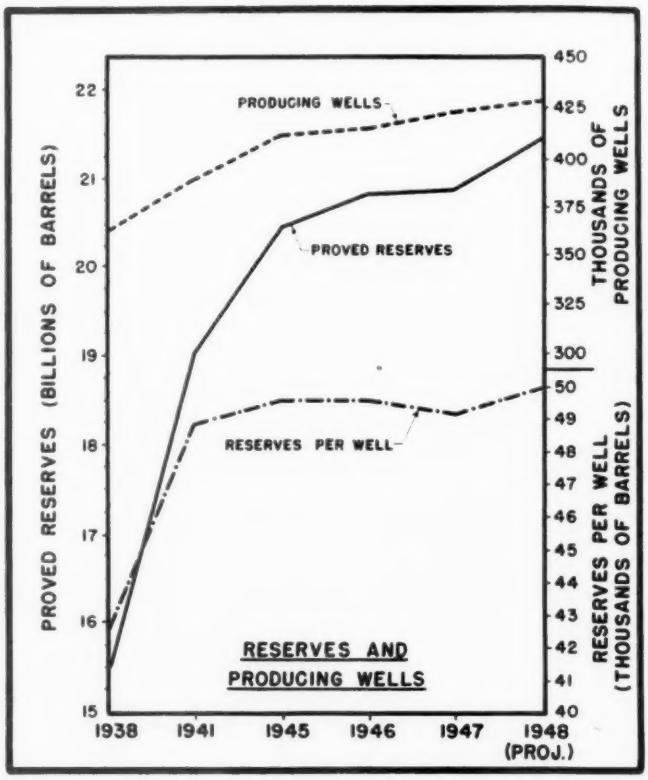

FIG. 8.

otherwise be accomplished. Despite the lack of steel, the industry will drill at least 12,000 exploratory wells and may reasonably be expected to drill a total of 34,000 wells, exclusive of service and input wells. This will top all previous records of drilling operations.

Preliminary figures indicate that the initial cost of finding oil in the United States last year was about 59 cents per bbl. (Fig. 7.) This compares with an average cost in 1935-38 of 13.5 per bbl. The cost of drilling exploratory wells, including dry holes, averaged $48,750 in 1947, compared with an average cost in 1935-38 of $13,600. Not only have all costs increased, including labor, equipment, and taxes, but the rate of discovery per exploratory well has also shown a material decline.

In 1947, the average rate of new oil discovery per well was about 175,000 bbl, whereas in the period 1935-38, the average discovery rate was about 325,000 bbl per well. This, coupled with high costs of exploration, including lease costs, has been responsible for the sharp increase in unit oil finding costs. These facts tend to minimize the size of oil company profits. Those outside our industry who criticize and glamorize oil industry profits should consider today's profits in the light of replacement values. It now costs four to five times as much to replace oil discoveries of prewar years. Oil company profits provide the means by which the industry is able to reinvest the huge capital expenditures necessary for exploration and replacement of oil and gas reserves. And let's not overlook the fact that whereas net profits of 27 large oil companies in 1946 were $3.71 per share, direct federal and local taxes averaged $2.38 per share. Government fares particularly well from the profits of the oil companies.

If you divide the total proved reserves of crude oil by the number of producing oil wells you get an average reserve of 50,000 bbl per well. (Fig. 8.) In the prewar year 1938, the average proved reserves per well was 42,700 bbl. During that period the number of producing wells has shown an increase of about 69,000, so that it is evident the reserves situation has continued to show substantial improvement, despite the unprecedented rise in demand for petroleum products. One of the most fallacious and misleading statements frequently made about oil is that the proved underground supply will last only 10 years at present rates of demand. Even if all exploration ceased overnight, it would take a period of from 30 to 50 years to recover all the proved reserves in sight. Oil men know that production rates are not stable, that reserves withdrawn from the underground reservoir must be replaced by new discoveries to maintain necessary production schedules. Ever since 1859, when oil was discovered by Colonel Drake, the industry has recognized this fact and has managed well to search for and find new reserves necessary to the maintenance of economic production schedules.

In bygone years the industry found far more new oil than was required to maintain normal production schedules and prices were depressed to uneconomic levels. Today, with sound conservation practices, sponsored by the industry and legalized in a majority of the oil states, successful efforts to find larger than needed reserves are no longer detrimental to the industry's price structure. Production is controlled within proper physical limitations and discoveries of large oil reservoirs like East Texas no longer carry the threat of unrestricted development and overproduction.

Domestic demand for petroleum products over the last ten years has been phenomenal. All types of consuming units, including motor vehicles, have increased by leaps and bounds, as indicated in Table 3. The petroleum industry has been well aware of this growth in consuming units and has maintained its operations in conformity with consumer requirements to a degree that exemplifies its high standards of efficiency.

Oil men know their business best. The record of their accomplishments cannot fail to instill public confidence. But, the public cannot be expected to sift and judge the many conflicting statements made about our industry and it appears that the weight of adverse comment has more than counterbalanced favorable, fact-founded information about oil. Public confidence can be won by time-honored performance records of our industry and the unchallengeable leadership of the men behind it. More emphasis on past performance and projected, long-range plans will show that the oil industry may continue to be depended upon to provide with maximum skill and efficiency and with minimum waste the constantly increasing demand for petroleum. Its operations are founded upon a long-range program based on awareness of immediate and future consumptive requirements. Oil men do not have to be prodded to action; they may be counted upon to act in any emergency and they are usually several steps ahead of those who do the prodding.

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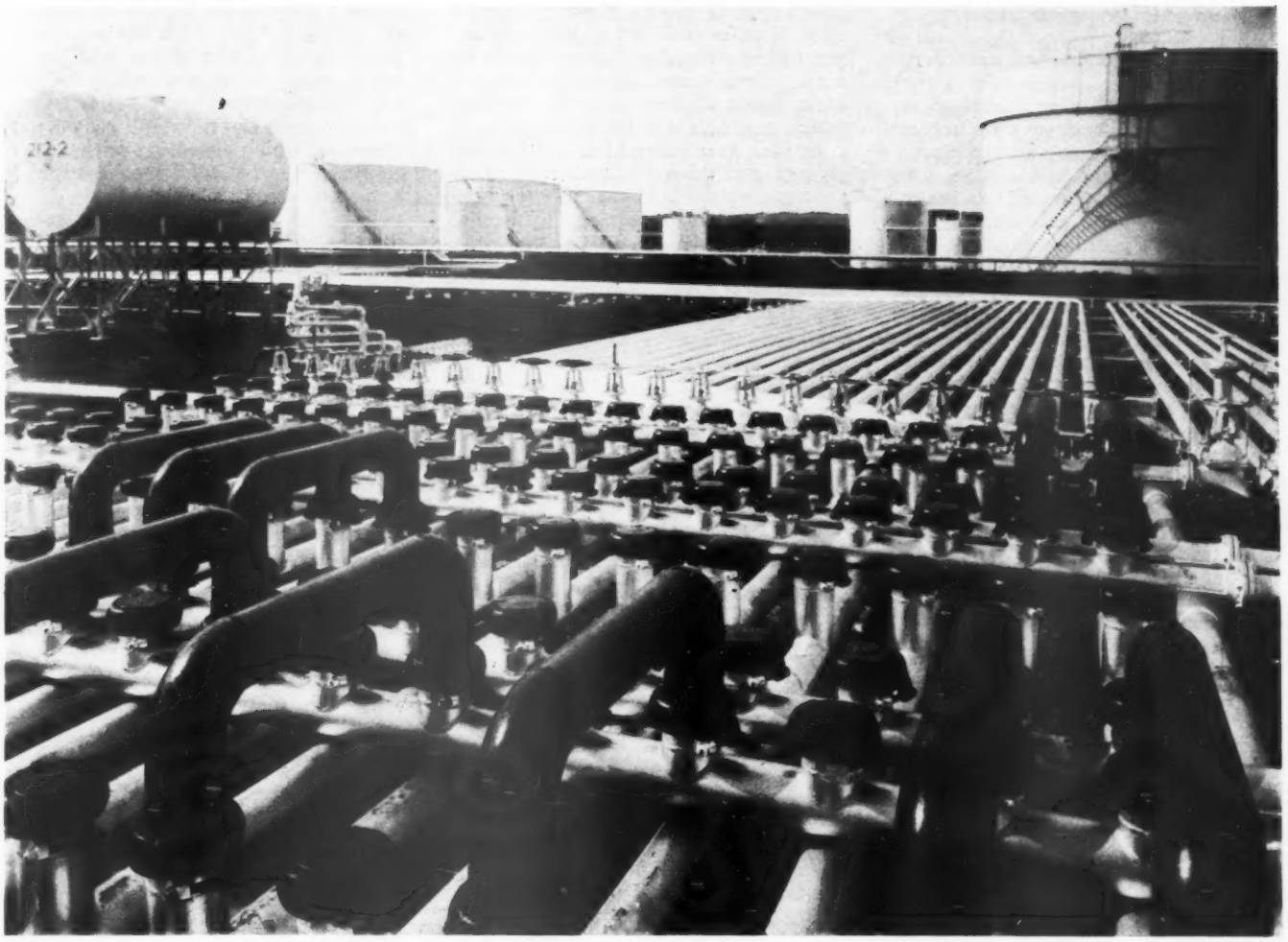


Segregation of products and flexibility of tankage is accomplished by the loading manifold with its swing arrangement. Individual pipes to each tank makes it a separate unit and also permits its rapid reconversion to different products when desired.

Expansion of Great Lakes Pipe Line

THE expansion and modernization program of Great Lakes Pipe Line Company, begun in 1945 immediately after the end of the war with Japan, has been completed.

As a result of the approximately $30,000,000 expenditure, capacity of the system has been increased 50 per cent, giving it a daily operating capacity of 104,600 bbl and new lines have brought total mileage to 3134.96. This makes the Great Lakes mileage the longest of any products pipe line system in the United States, and its operating capacity the largest.

The total program involved laying of more than 1200 miles of lines, the construction of 14 primary pump stations, eight new delivery terminals, the remodeling of the buildings and facilities at 14 existing pump stations, and two terminals on lines from Tulsa, Oklahoma, to Minneapolis, Minnesota.

Major portion of the line construction was in the projection of a new route from Kansas City northwest with terminals at Omaha, Nebraska; Sioux City, Iowa; Sioux Falls and Watertown, South Dakota; Alexandria, Minnesota, and Fargo and Grand Forks, North Dakota. These terminals are all new with the exception of Omaha, which formerly was served by a line from Osceola, Iowa. Grand Forks, the northern end of the line, is 65 miles from the Canadian border.

In addition two other terminals were constructed, one on existing lines at Mason City, Iowa, and the other at Mankato, Minnesota, from a connecting line to Albert Lea.

An understanding of the motive or goal of the construction program is helped by a knowledge of the company's operations. Unlike many other pipe line companies that operate as common carriers, it has a relatively large number of points of origin of shipments. At present it is receiving through its own lines from 19 refineries at Oklahoma and Kansas towns, and from a line owned jointly by Sunray Oil Corporation at Allen and H. F. Wilcox Oil and Gas Company at Bristow, to Drumright, Oklahoma, where it joins a Great Lakes line. An interchange agreement with Phillips Petroleum Company, products pipe line

division, adds two more refineries at Borger, Texas.

Few of these refineries have large storage facilities, which means that Great Lakes has to move the shipments as soon as possible after they become available. This is in contrast to the practice of some companies, which are able to have the products pumped to a central point for pipe line shipment as line space becomes available.

All terminals to which Great Lakes lines are connected are owned by it and the company is responsible for each shipment until the product is loaded into motor transport or tank car for jobber distribution. This, too, is in contrast to pipe line companies that deliver to terminals owned by a distributing company, where the moment a shipment enters the terminal it becomes the property of another company.

With a large number of shippers there is a proportionate demand for the handling of more grades of products and for a smaller minimum shipment barrelage with consequent task of segregation, both in movement and in handling at terminals. To solve this problem as efficiently as possible is the purpose back of the designs that have for their basis the maximum handling of nine different grades. The ultimate achievement in this respect is the new transport loading machine where the operator has at his finger tips immediate control over the loading of nine grades of products.

In order to get the needed flexibility, many of the improvements, especially at terminals, necessitated a larger initial investment than an alternate plan would have, but measured by a period of years the plan used is definitely less costly and is, of course, more efficient in daily operation.

During the planning stage shippers asked to make an estimate of their transportation needs in the areas that would be served by the enlarged system. Based on these forecasts, the capacity was set at a figure that it was indicated would take at least five years to reach. By the summer of 1947 Great Lakes was moving that amount of traffic, and before the permanent construction was completed, temporary secondary stations using adapted aircraft engines as prime movers were being built to increase further the capacity of the system.

The study from which the construction program developed indicated the cities in which new terminals would be located. It was the desire of Great Lakes management to establish these points fairly close together, giving shippers an opportunity to increase the pipe line portion of shipments and decrease the distance necessary to move products by tank car or motor transport into consuming territories. Terminals on the new northwest line are approximately 100 miles apart.

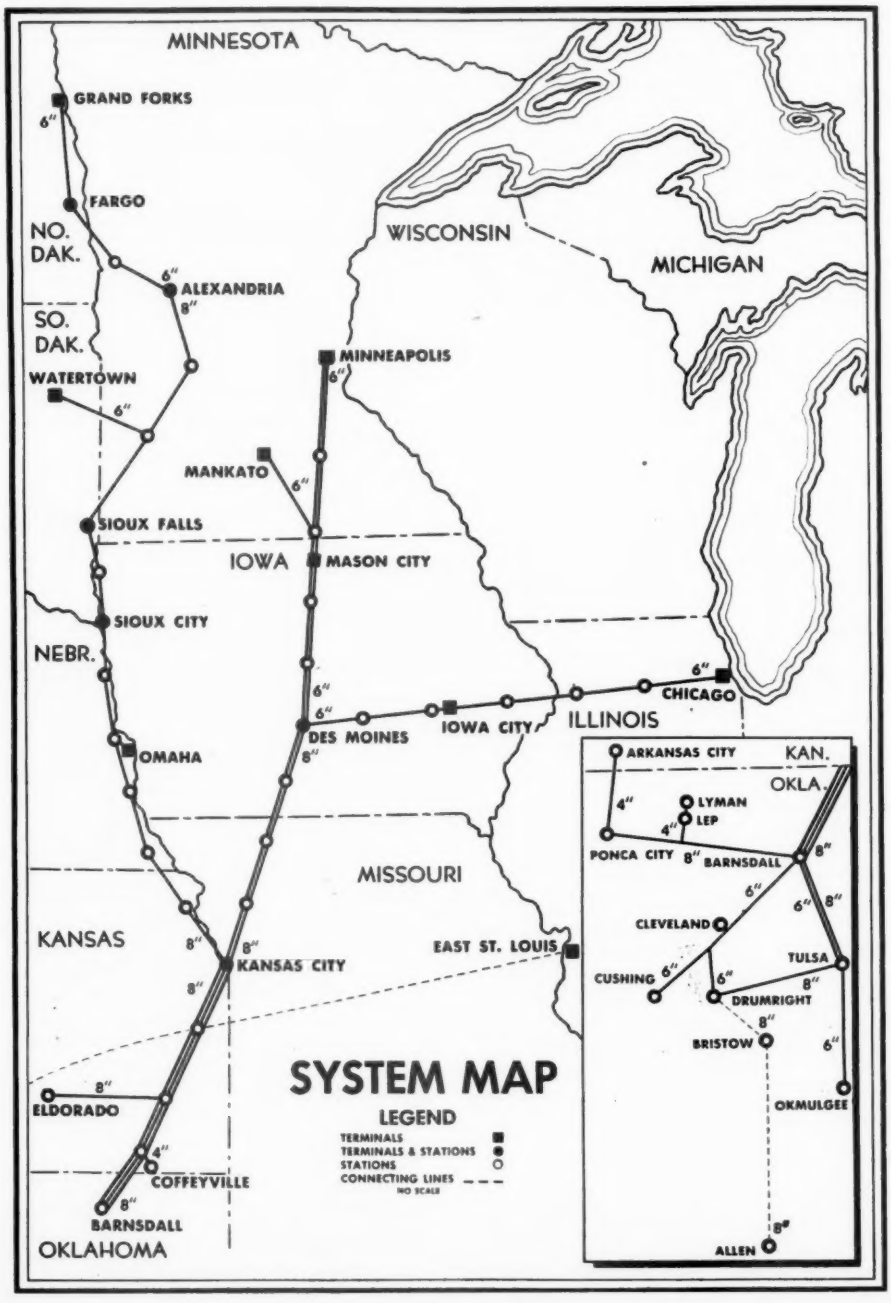
Factors involved in choosing a terminal site include present space requirements, room for possible expansion, and terrain. Careful attention also must be given to outbound rail and highway transportation. Obviously, it is a difficult assignment to select a property of from 20 to 40 acres outside the city limits and yet within switching facility of one or more railroads and also convenient to a main paved highway into the territory where products will be delivered.

In each case several tracts were considered and the advantages and disadvantages weighed. At each city the company was able to acquire the favored site.

Preliminary to the construction in the territory northwest of Kansas City, the best available maps of the area were obtained. From these a general route was selected between the then known points, the terminal cities. With this route as a guide an aerial survey was made from which maps were constructed by the use of photogrammetry. This is an involved process but the result is an aerial survey on which distance, together with elevation, may be calculated directly and accurately from a photograph.

With this information before him the locating engineer proceeds to select the exact route the line would follow. Land plats giving its course through each property were prepared and supplied to the right-of-way agent.

The 3,134.96 miles of Great Lakes Pipe Line Company lines traverse nine states, with delivery terminals in seven of them. The broken lines on the map indicate the pipe line from Borger, Texas, to St. Louis of the Phillips Petroleum Company, products pipe line division, with which Great Lakes has an interchange agreement. The line from Allen and Bristow, Oklahoma, is owned by the H. F. Wilcox Oil and Gas Company and Sunray Oil Corporation.



As winter was at hand in the northern states by the time these men began to work the weather was a factor in their daily trips, but it failed to deter them. They traveled to farm houses by automobile, horse and buggy, by sleigh, and at times when roads were closed to these methods they donned skis and snow shoes.

When the permits were obtained a ground party set stakes for the line at proper intervals to guide the contractor who had been chosen on the basis of bids made on company specifications.

Permission of the War Department was required for river crossings; of the Missouri at Decatur, Nebraska, the Red River at Fargo, North Dakota, Minnesota River at Granite Falls, Minnesota, and the Kaw at Kansas City. Along the Missouri River, especially in Nebraska, large drainage canals were encountered. Wherever permission of the drainage districts could be obtained for construction of supporting towers the line was suspended over the canals. Three of these averaged 250 ft in length and it was required that the pipe have a clearance of 40 ft to permit the passage of draglines used in cleaning the canals. Suspensions of this height necessitated careful engineering and the use of heavy supporting towers and anchor fixtures. Nevertheless, the cost of such crossings is less than putting the line underneath.

All pipe was received from the supplier in double random lengths of approximately 40 ft with end caps applied. These caps were removed immediately prior to welding the joints.

The 8-in. pipe has an outside diameter of 8.625 in. and an inside diameter of 8.219 in. with a weight of 18.26 lb per ft. About half the pipe was electricweld and the other seamless.

The 6-in. pipe, all electricweld, has an outside diameter of 6.625 in. with a wall thickness of 0.1875 in. and a weight of 12.89 lb per ft.

The electric welding process was used to join the pipe. After the lines were laid they were machine cleaned and a fast drying primer coat was applied. This was followed by two coats of coal tar having a total thickness of 5/32 in. and a spiral wrap of asbestos felt completed the coating. Electric rectifiers supplied with purchased current were connected to the line at proper intervals to provide cathodic protection throughout the length of the new line. The line was buried with a maximum of 24 in. of cover except where otherwise necessary because of crossings or other requirements. Across cultivated fields a minimum cover of 24 in. was used.

Inability to obtain pipe on any sort of schedule delayed for weeks completion of this work. On many days the distance laid was determined solely by the amount of pipe received on that day.

Gate valve boxes on the line are 6 ft square, 5 ft deep, and are made of transite, a material impervious to moisture. A coupling is attached on both the upstream and downstream sides of each valve so that in event of line pressure loss its location can be traced by a process of checking pressures in successive line sections.

When the line is shut down the downstream valves are closed and a pressure reading is taken by a gage attached to the coupling. The worker then moves on to the next gage where he takes a reading. This is done until he has covered an assigned distance. Then he returns to the original coupling and repeats his trip, taking readings at each coupling. When a section shows a decided pressure drop it is immediately investigated.

Prime movers are vertical 6-cylinder, single-acting, 4-cycle turbo supercharged diesels that develop 810 hp at 600 rpm. The engine is an exact duplicate of those used for locomotive power. Distillate is used for fuel but at present a test is being made on an engine converted for use of natural gas. Great Lakes engineers say the economy of operation is attractive if the design can be made practical. The engine can be reconverted for distillate by half of a turn of a lever. This is the first attempt made to change this type of engine to natural gas fuel.

Pumps are 6-stage centrifugals driven by a speed increaser at a 5.978 ratio.

Flow rates are governed by a Fulscope controlled by an air bellows. Suction pressure is the determining factor, within certain limits. When the safety limit on the discharge side, set at 50 psi above normal operating pressure, is reached the discharge side of the Fulscope takes over control of engine speed regulation, thus preventing the engine from reaching a speed that would build up pressure that likely would cause line breakage.

Heat exchangers for both the lube oil and engine coolant are placed vertically underneath the floor within the building. This method obviates the necessity for draining the exchangers when not in use in extremely cold weather and also makes for a neat appearance.

The engine heat exhaust is utilized to heat the station. Heat from the engine is transmitted to the boiler room where it generates steam and passes it through coils. A power blower feeds air across coils where it is warmed to approximately 110 F and carried through ducts to ceiling diffusers in the rooms that are to be heated. Air from the engine and pump rooms is taken out by power exhausters to remove all dangers of fumes.

The rooms react to heat demands through thermostat control and temperatures are maintained within one degree of the desired figures.

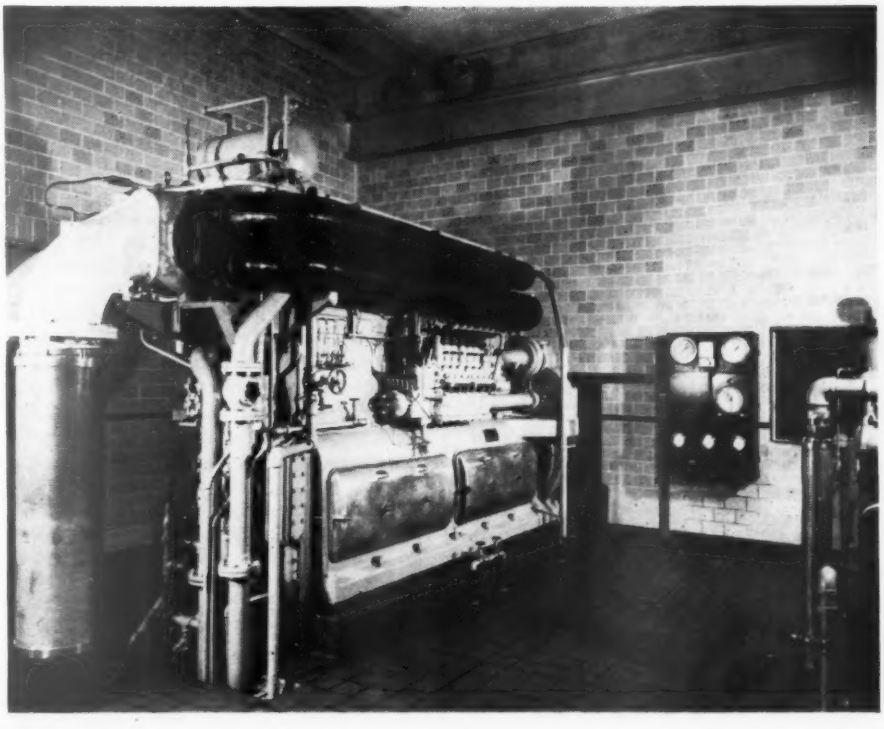
When the engine is not in operation, heat for the boiler is supplied by a distillate burner. When operated in this manner, the exhaust pipe of the engine is closed off from the boiler to prevent any high temperature gases from going back and damaging the diesel assemblies.

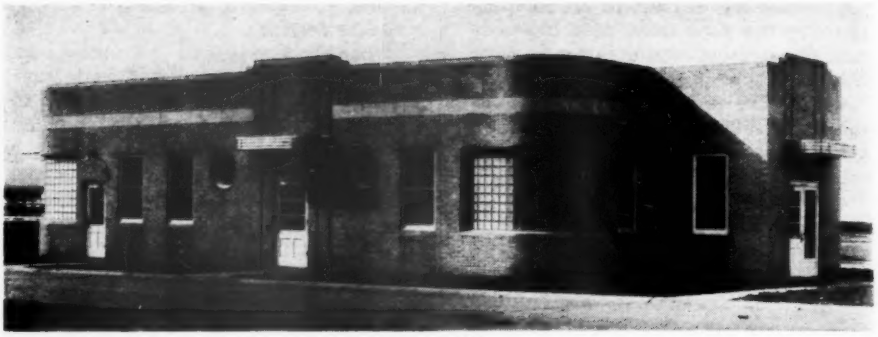
Water wells at the stations are indoors. The building lights are flush mounted in the ceiling, vapor tight and equipped with pressurizing connections. The wiring system utilizes breaker points for overloads instead of fuses.

A construction feature that has aided in maintaining comfortable floor temperatures in all buildings is a cold-break. It consists of a trench inside the foundation and under the floor, a foot wide and a foot deep filled with asphalt.

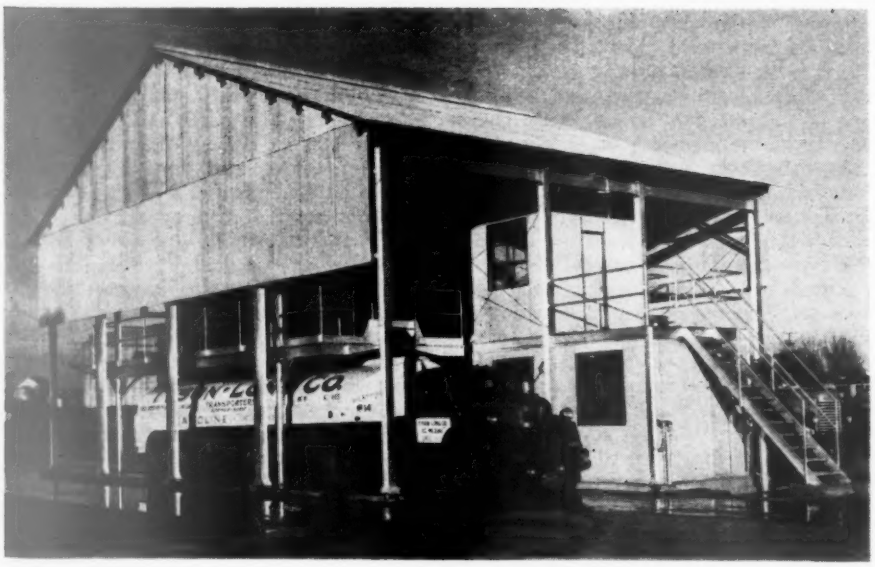
All buildings are of tan brick and tile construction. Ceilings are of off-color white paneled acoustic material that helps to reduce the noise level of the

Good housekeeping at stations is made easier by the tile floor, walls, and an acoustical paneled ceiling with a baked enamel finish. Even the stratosphere blue paint of the diesel engine, when waxed, may be washed.





Below, tank truck loading dock. Perfectly safe loading conditions are assured the operator of the loading machine by the platform, which is borne by hydraulic supports and which may be adjusted to the exact height of the transport loading domes. Controls for loading of nine different grades of products are instantly available.



Appearance is combined with utility in the new virtually maintenance free buildings. The terminal service buildings and the pump stations are similar and at the terminals the buildings harmonize as a group.

rooms. Machinery is painted stratosphere blue. The floor of rust color and a narrow green horizontal wall stripe against the peach walls 4 ft up and chocolate color cove base tile combine to give the interior a pleasing appearance, make housekeeping easier, and greatly lessen maintenance.

Auxiliary equipment includes an air compressor, a generator where purchased electric power is not available, and a water well pump. Yards are graded and landscaped and the entire area enclosed with a chain length fence.

Design of the new terminals represents a decided improvement as compared with former facilities. From an adjoining highway, Great Lakes has built two concrete roads leading to the transport loading machine. Nearby is the tank car loading rack. Between the two lines of traffic is a building of brick and tile, 65 ft long and 30 ft wide, which houses the office, laboratory, heating plant, and store room.

In the completely equipped laboratory a chemist makes tests of all products. These are made on incoming shipments and again before the products are loaded out. The electric gauging dial in the office provides a means by which a reading may be taken instantly of any tank on the farm, correct to within an eighth of an inch.

The walls and floors of these buildings are tile construction and the ceiling of acoustic material to reduce maintenance to a minimum. The heating system is thermostatically controlled.

Steam is produced in the boiler house and in water piped under pressure to the loading racks for thawing outlet caps and dome covers on motor truck transports and railway tank cars.

The tank farm and delivery system gain interest both by the facilities they have and also by much they do not have. In the latter category, they do not have an imposing maze of complex equipment at a central pump house, the piping is not an intricate weave of cross-overs, switches, and numerous valves.

Simplicity is the keynote of the new arrangement. Each tank is a separate unit complete in itself, having its own receiving and delivery lines, transfer pump, and circulating system. With these facilities it is able to perform four functions: Receive, circulate, blend, and load, without interfering whatsoever with any other tank.

This system allows a tank changeover from one product to another to be made easily and quickly by the operating crew. Under the former method it was necessary for a special group to revamp the tank piping and pump connections, an expensive procedure in both time and money.

In case of heavy demands for a product, two or more tanks may be connected to common delivery facilities within five to ten minutes. The extreme flexibility of the system is illustrated by the 3802 two-tank combination hook-ups possible at a 20-tank farm.

Having individual pumps at each tank also has done away with the bugaboo of vapor locks that prevailed at some of the gravity feed delivery systems.

Transfer of incoming products from the main line is accomplished by connecting the swing line of a cartwheel arrangement in the products segregator room of the pump building to the tank's receiving line. Delivery from a tank to any common carrier is made by changing a nipple at the unloading manifold. As all lines are above ground the product flow can be traced quickly and easily. The elimination of the manifolds prevents contamination and carries on the basic idea of the entire system of making connections as short coupled as possible.

Each tank has a separate circulating system, but where tetraethyl lead is introduced into all tanks it is done by a common line. The lead tank is housed in a separate building, which has on one end a room containing the dye pot from which dye is introduced into the gasoline. The brief time necessary to induct the lead and dye is the only period the common line is tied up. After these have been introduced the tank is circulated. With the new design tank spider is a small hydraulic pump, which greatly speeds up the operation. The circulation for any tank is completed within 30 min.

The tanks are cone roof, connected with lifter roof tanks in a vapor recovery system. As many of the terminals are in regions where ice, sleet, and snow are commonplace in winter the lifter roof type tank is preferred. Low vapor products are handled in the cone roof tanks without vapor recovery connections.

Inside the tank, the upper half of the suction line for withdrawing products is cut away to provide a trough. Because all the product has to enter the suction line from the top, water on the bottom of the tank is prevented from entering the loading system.

The water pump is placed at the lowest place on the bottom of the tank and prevents the loss of product by eliminating a vortex formation during the withdrawal of water.

Tank gaugers carry a magnetic telephone set and may if they desire plug in

at a connection at each tank. The tank has vent and vacuum valves for over pressure and to prevent vacuum collapse. Each unit is grounded against lightning and they are enclosed within firewalls of 100,000-bbl capacity, equal to or greater than the barrelage of the tanks that they enclose. Tanks are covered with a high luster chalking paint that retains a slight amount of moisture, tending to have a self-cleaning effect.

The new loading machine for motor transports is probably the most complete in existence and represents the greatest improvement over conventional design of any facility on the system. It was developed to correct the bad features of loading racks formerly used by affording safety for the operator and by increasing the speed of loading.

Its center of operation is a series of pantograph piping, which may be moved up and down and back and forth to reach transport domes of motor carriers. To prevent the pipes from twisting out of position they are restrained by a six-pulley trolley, which is guided in its travel by sets of beams. The group somewhat resembles in appearance the adjustable extension of an industrial extension telephone.

The loading platform rests on hydraulic plungers installed beneath the roadway. When a transport pulls into a loading stall the platform is at its highest position. The operator presses a button, lowering the platform to a level with the top of the transport where he can move in all directions with perfect safety. He removes the dome covers, pulls the pantograph into position, and attaches the downspouts. Back on the fixed platform he adjusts the set stops, inserts the bill of lading into the automatic printer, which registers the gallonage and starts the flow of products.

The set-stop cuts off the flow at the predetermined level, the loader removes the downspouts, seals the dome of the truck compartment, and removes the bill of lading from the printer. Then, with a push of the button, up goes the loading platform and the transport is cleared for departure.

The operator can start and stop the electric pumps at any of the tanks from the fixed platform.

The tank car loading rack and the motor transport loading machine are interlocked both hydraulically and electrically, but the electric control panel at each point operates separate relays. This provision is to take care of the pump motor stops and starts when both are loading from the same tank. The first operator to push the start button closes the pump contact switch and starts the pump, the last one to push the stop button releases the switch. This arrangement prevents one operator from stopping the pump when the other has not completed his loading operation.

Possibility of damage from the unavoidable contraction and expansion of pipe runs has been eliminated by using long gradual pipe bends at appropriate positions.

In the modernization program of existing line, the problems were much the same as those on the new route with the exception there were fewer right-of-way easements to be obtained and fewer terminal sites to locate. One of the big obstacles was at pump stations where the work had to be carried on without disrupting normal operations.

A third 8-in. line was laid on the 204-mile route from Barnsdall, Oklahoma, to Kansas City and a new 85.76-mile line was laid to this section at the Humbolt station, from refineries at Eldorado, Kansas. Between Ponca City and Barnsdall two 6-in. lines were replaced with an 8-in. line. The 6-in. pipe in the No. 2 Tulsa-Barnsdall line was replaced with 8-in. These changes provided lines with matching capacities between these points and the Barnsdall-Kansas City lines.

At primary stations north and south of Kansas City the former policy had been to use two units for each line with each unit supplying half the pumping capacity. In nearly each case the unit had consisted of a reciprocating pump driven by a diesel engine.

The new policy carried out in the modernization was to replace these units with a single centrifugal pump driven by the same model diesel used on the new line. This meant that the number of pumps and engines at each station was halved. At the Kansas City station three electric Rannett units were installed.

The former method of underground tank lines at terminals and transfer points also was abandoned and they were brought above ground. The old type incoming manifold was replaced with the simple cartwheel arrangement.

Installation of these new units and pipe arrangements achieved the same result as on the new line, greatly reducing the commingling of products and increasing the ease and flexibility of their segregation in handling.

Not only were the equipment and facilities modernized, but also the buildings. Interiors of the stations were completely remodeled. New tile floors were laid, ceilings were replaced with acoustic panel material, which is continued down the walls to within 7 ft of the floor where it joins a 7-ft tile dado, which is topped with an aluminum horizontal stripe above a green tile stripe at the 4-ft level. These changes give the stations the benefits of the latest type construction with its reduced maintenance and better appearance.

A program such as this even in normal times is an enormous undertaking. During the period in which it was carried on it assumed the proportions of a battle. There were several factors that helped to account for its successful conclusion.

The first was getting an early start. As rapidly as requirements were determined materials and machinery were ordered. An investigation of building material available showed that no matter what was chosen its procurement would be a problem. Experience has proved that a brick and tile combination provided the best building, and it was decided not to lower company standards by accepting anything inferior.

The management gave orders to ship all material as soon as it became available, no matter what it was. Wire, nails, screws, and numerous small items that ordinarily would never have been stored were taken as soon as they could be obtained and stocked in warehouses along the line from Oklahoma to the Canadian border. The wisdom of this course was proved many times; in one instance nails disappeared from the market. The saving in time of construction was tremendous.

Another innovation in building procedure allowed the new line to be placed in operation months earlier than otherwise would have been possible. Several temporary steel buildings were purchased and erected on the permanent buildings sites. This was done so that if permanent construction became impossible and pumps and engines arrived operations could be carried on under these shelters temporarily.

As pumps and engines were received they were set and put in operation in these temporary buildings, which were considerably larger than the permanent structures. When materials arrived construction progressed under the temporary buildings. This had still another advantage. Brick layers were able to work under protection from the elements. In the northern states this was especially advantageous as they were able to remain in their home town rather than having to go south to work during the winter.

As soon as the roof and walls of the permanent buildings were completed the temporary structures were taken down and moved to another location. In these communities people were treated to amazing one-day transformations. Driving by a Great Lakes station in the morning they would see the usual metal building. By evening a modern brick building had appeared in its place.

While this procedure permitted line operation it meant that station personnel had to work under conditions similar to what a family would undergo if it were to move into a residence as soon as the walls and roof were constructed and the floor in one room partly laid.

It was in this manner that the system operated for months at an enlarged capacity, moving millions of barrels of product to an area that was constantly demanding more gasoline, more distillate, more fuel oils.

Hesitancy in the start of construction or a slackening of effort at any of the stages of the program would have meant a further delay of months. ★ ★ ★

Turkish well

It is reported from Turkey that the Government oil company (Maden Tetkik ve Arama Enstitusu) has completed a well on the Ramandag structure that is swabbing 300 to 400 bbl a day. Drilling operations for the Turkish government are under the supervision of Drilling and Exploration Co., Inc.

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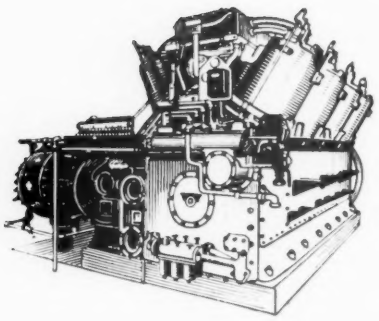

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Production and disposition of natural gas by California producers*

By E. K. PARKS, *Petroleum Production Engineer*

THIS ARTICLE is intended to be a brief picture of the development of conservation practices in the oil industry resulting from the growing realization by operators of the importance of restricting gas production and maintaining pressure.

Pressure maintenance projects that have been developed from these studies are for the purpose of increasing the total amount of fuel that will be produced in California over the long run. Whereas, the injection of gas causes a temporary reduction of the supply currently available, the ultimate yield of gas will be reduced very little by such projects. Where installed they increase the yield of oil from a particular field by from 50 to 100 per cent. In the opinion of the author, this alone is sufficient justification for their continuance.

INTRODUCTION

● **Definitions of gas.** Any petroleum product that is in a gaseous phase under ordinary surface temperatures and pressures is a natural gas. Various condensable petroleum compounds may be associated with natural gas, and if present in sufficient concentration to justify extraction the natural petroleum gas is termed "wet gas." Otherwise, the gas is known as "dry gas," a term that is also applied to the residue after treatment to remove condensible hydrocarbons, commonly known as liquid petroleum gas and natural gas gasoline.

● **Occurrence and exploration for natural gas.** Natural gas occurs in geologic structures in exactly the same circumstances as petroleum liquids. The natural reservoir may, however, contain almost exclusively the natural gas in gaseous phase, or a partial accumulation of gas resting upon liquid oil, or almost exclusively liquid oil in which methane, ethane, and other constituents of natural gas are dissolved. A prospector must anticipate exploiting whatever petroleum product he may find and, whatever it is, the geological problem, the drilling of wells, the production practice, the machinery used, and technical talent employed are the same. Thus, the occurrence, search for, and production of natural gas are all a part of "the oil business."

Exploration for oil in California, when when successful, results also in discovery of gas, which occurs in reservoirs partly as a separate accumulation above the oil (as a gas cap) and partly in solution in the liquid oil. The quantity of gas originally dissolved in oil ranges from a low of 300 cu ft per bbl to a high of as much as 1000 cu ft per bbl, the actual amount being dependent upon gravity of the oil, the temperature and pressure of the reservoir, and the saturation of the oil in that reservoir.

● **Development of properties.** Once discovered, a dry gas field pays out only through production of gas. It follows that such a field must have a pipe line outlet, which is installed and operated by the gas buyer. In California, a dry gas field is seldom out of practical reach of a pipe line, although a buyer demands proof that production will be available in sufficient quantity and rate to justify his investment, which depends upon knowledge of the reserve of gas and performance of the wells. Hence, the operator may be obliged to drill several development wells and demonstrate reserves by various tests before he can interest the buyer.

A discovery of oil, and the gas associated with it, results in a revenue from crude oil, natural gasoline products, and dry gas residue; the latter two sources awaiting proof of supply, unless facilities for gas gathering and treatment are already fairly near at hand, say within five miles.

The development of the newly discovered oil and gas field proceeds in accordance with lease terms, competition, availability of materials, geological information, and the multitude of technical and economic considerations that influence oil field operations.

Development of an oil field differs from that of gas field in the matter of well spacing more than in any other respect. Gas wells may effectively exhaust a reservoir if spaced as widely as a mile apart in a field where the structure is unbroken by faults and the productive sand is continuous. Wide spacing is practical because gas migrates through sand pores with great ease. Crude oil, however, is viscous and oil wells are drilled on a spacing in California that commonly varies from one well to five acres to one in twenty, there being exceptions with respect to maximum and minimum. An operator usually will attempt to recover the maximum oil with the minimum wells insofar as circumstances permit; that is, in accordance with his lease obligations, in consideration of competition adjacent to his property, and as controlled by the rate of production per well. In furtherance of reduced cost of development, that is, fewer wells, the operator turns to methods that will cause oil to migrate farther in less time. Thus, oil production methods are intimately related to a development program. This relationship has a direct bearing on gas production from an oil and gas reservoir, as will be explained later.

● **Production of gas from a dry gas reservoir.** In California, the rate of production from a gas well in a dry gas reservoir has a practical limit that is far below its open flow capacity. This limit is controlled by sand, water, and the pressure at which gas leaves the wellhead. A gas well production rate is restricted to prevent destruction of the well casing by the cutting action of sand, to avoid damaging of water, and to maintain a well outlet pressure that permits forcing the gas into gathering systems.

The greater the rate of production from a gas well, the less is the surface pressure. This pressure must always be greater than the pressure of gas in the gathering system, if the well is to produce directly into the line. It follows that native reservoir pressure is a great asset and operators strive to keep their wells in condition to utilize it.

A dry gas well produces by natural flow. In the early stages in California fields, the output pressure is sufficient to deliver the gas into high pressure gathering lines without artificial compression. As the reservoir is depleted, the output pressure declines and the gas must be compressed for transmission. Hence, the delivery pressure of gas is important in any gas contract.

● **The dry gas reservoir in a utility system.** A dry gas reservoir provides the most safe, serviceable, and economical form of gas storage. Furthermore, such a reservoir is usually connected to a gathering system that is under the control of one gas company buyer. It follows that a dry gas reservoir, being independent of oil production, is an ideal source of supply for a utility. The usual gas contract gives the utility the right to determine the quantities and rates of gas, within broad limits and consistent with prevailing operating practices, that the utility will take from the individual seller. Wells are opened up, pinched back, or shut down to conform to these requirements, with the exception of some wells that must be kept on continuous production for special reasons, such as edgewater encroachment.

Because of the flexibility of production of a dry gas field, operators at Rio Vista are not only supplying natural gas, but are supplying it at high production rates in winter and low ones in summer. Other dry gas reservoirs in the region operate much the same as Rio Vista.

*Condensation of statement before California Public Utilities Commission.

● **Production of gas from oil and gas fields.** As for natural gas from oil wells, production practice is entirely dependent upon oil production. It is impossible to produce crude oil without producing more or less natural gas that is contained in the oil reservoir. Such gas is enriched by its close contact with volatile liquid fractions of crude. Hence, oil well gas is usually "wet gas." The proportion of gas produced with oil is measured in terms of cubic feet per barrel of oil. The ratio varies from as low as 50 cu ft per bbl to as high as 10,000 cu ft per bbl with special cases still higher.

Oil wells are restricted in rate to something less than actual capacity, for the same reasons that apply to gas wells plus another important objective—to keep the gas-oil ratio down. It has been demonstrated time and again that the gas-oil ratio is increased as the oil rate approaches capacity of the well.

It is appropriate here to record that much oil and gas land is not owned by the operator, but is leased for the purpose of extracting petroleum hydrocarbons therefrom, in accordance with the terms of the lease, which, especially in California, is full of detailed specifications. In return for this privilege, the operator pays a royalty to the lessor upon the production, but at the same time does not have absolute freedom of operation.

Production costs are a minimum with flowing wells, but immediately that natural flow ceases the operator is faced with a large capital investment for pumps, enlargement of field personnel, and a persistently increasing lifting cost. Hence, it is desirable to maintain a flowing condition as long as possible, or, more constructively, to obtain the maximum yield from the reservoir by natural flow.

● **Disposition of natural gas by producers.** Oil well gas production is inherently a function of the oil well performance. The operator must immediately dispose of the gas, which may be insufficient for his own needs or his surplus may exceed the capacity of any available gathering lines. The primary gas collection facility in an oil field is the gasoline absorption plant, but it is designed for a certain capacity with gathering lines to operate at pressures consistent with the entire system. Changes cannot be made without investigation, analysis, money, material, and labor. Expensive plants and lines large enough to care for peak output are economically unjustified. Sudden changes in plant throughput are dangerous, wasteful, and costly. Thus, the operator is forced to conduct his oil operations so as to take care of gas disposition. He plans his operations accordingly. These plans affect the size and capacity of his equipment, his personnel organization, and, hence, his long term outlook. The overall result is that oil field operations follow a design that is transformed into physical equipment and trained personnel, all to work in harmony with lease requirements, oil pipe lines, and gas handling. This coordinated business can-

The author

An independent petroleum production engineer, E. K. Parks was engaged by the Natural Gas Producer's Association of California to present facts about discovery, production, use, and availability of natural gas to the Public Utilities Commission of California. He also appeared before the Federal Power Commission in connection with the recently completed California-Texas transmission line for his clients.

Parks entered the oil business through the U. S. Bureau of Mines in 1919, was graduated from Stanford in 1924, and was employed by Standard of California for the next 14 years. He was chairman of the Southern California Section AIME in 1938, of the Pacific Coast District API, Division of Production in 1942, and is the author of several papers on oil development and production. Since 1938 he has been a consultant in large scale oil field operations, unit plan projects, and valuation of oil and gas properties.

not function economically for the special benefit of any part. A sudden call for more oil results in more gas production and vice versa. Perhaps a call for an appreciable gas increase could be met without an important increase in oil rate, but this situation upsets carefully engineered plans of oil reservoir engineering and involves the entire gas handling system, including the absorption plant. Smooth and orderly operation is essential to efficiency of oil and gas production from combination reservoirs.

Gas disposition from a dry gas reservoir proceeds without the complication of an absorption plant or gas oil separation. The rates of production are thus more flexible and can be increased or reduced in accordance with changes in demand. Consideration must be given, however, to the rights and interests of landowners and operators as well as to the rights of the buying utility. Although operators cannot expect to sell all the gas they can produce all the time, it is unreasonable to expect an operator to shut in his well entirely; in other words, utilities cannot expect dry gas reservoirs to be run solely for their benefit.

● **An historical review.** In the early days of the California oil business, producers made no effort to conserve or dispose of the natural gas accompanying the production of crude oil, but with the advent of the casinghead gasoline plant, the gas produced from a number of wells was collected through field gathering systems, supported by the gasoline extraction business and made available at one place in the field.

The development of the gasoline extraction business led to the development of the natural gas business on a large scale. Utilities laid trunk lines to oil fields in which gasoline extraction plants were situated.

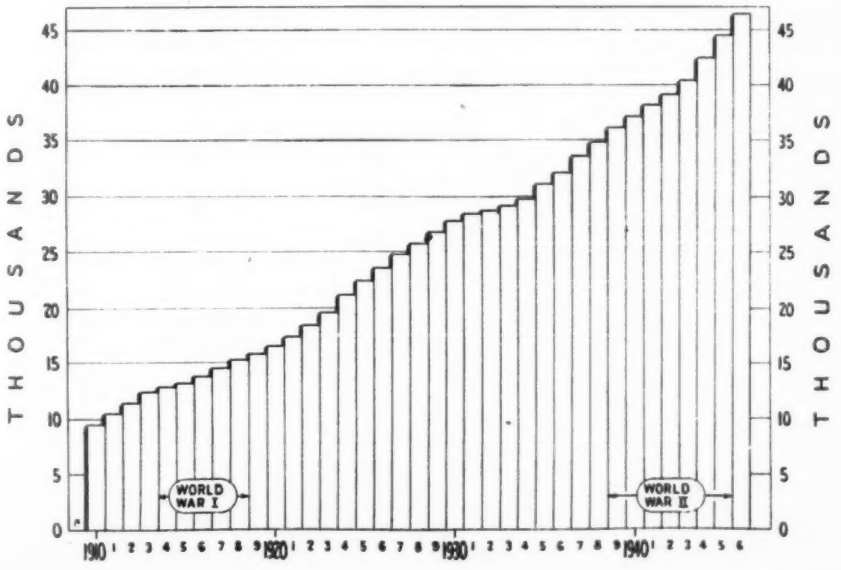
From the time of the discovery of the Signal Hill and Santa Fe Springs fields in 1921 until 1942, however, a period of 21 years, the production of both oil and oil well gas far exceeded the demand and large quantities of gas produced with oil were blown to the air.

One of the reasons was that the production of gas from the two fields in 1923 raised the state total to more than three times the rate prior to their discovery. It is obvious that no gas utilization plan could have kept pace with such rapid increase in production.

The same waste in varying degrees would occur today with the discovery of every substantial new oil field were it not for the improved production methods now practiced by oil producers.

These methods are the culmination of long experience, with particular emphasis upon applications during the decade beginning in 1930. Measures taken to increase ultimate production of oil involved restriction of oil rate and a simultaneous reduction of gas blow. Thus the oil and gas reservoirs were in

WELLS DRILLED—CUMULATIVE. CALIFORNIA, 1910 TO 1946

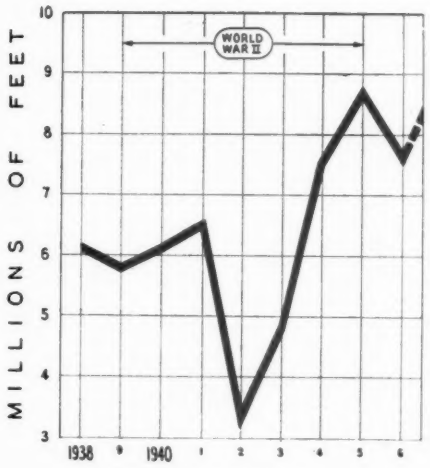


good condition to supply the remarkable increase of oil and gas production for the war demand. The California crude oil rate was raised from 651,000 bbl a day in the middle of 1942 to 942,000 bbl a day in the middle of 1945. This increase of 291,000 bbl a day is 44½ per cent of the 1942 rate. The fact that California producers could so stimulate production, without a major discovery, was a statewide demonstration of the success and efficiency of modern production engineering practice.

● **Progress in oil field technology.** The development of the casinghead gasoline business also caused operators to begin the measurement and testing of oil well gas to determine its gasoline content. This was followed by the measurement and testing of tank vapors. This, in turn, led to the discovery that these vapors contained large quantities of the gasoline and other of the lighter petroleum fractions. It was also discovered that evaporation from crude stored in open tanks not only reduced the volume of the tanked oil, but resulted in a reduction of its specific gravity and a marked increase in its viscosity. This fact led engineers to infer that the same thing would occur in underground oil reservoirs, if gas were produced at excessive rates.

Research showed that just as loss of gasoline vapors caused the remaining stock tank oil to become heavier, so the evolution of gas from crude in the natural reservoir caused the remainder to be heavier, and to increase in viscosity. Analysis of the mechanics of oil migration in natural reservoirs proved that the cause of decline of oil rate was not so much an exhaustion of oil as an exhaustion of pressure that forced the oil to the wells. Careful studies in laboratories throughout the United States disclosed the nature of reservoir rocks as agents for transmission of crude oil and natural gas. It was found that bubbles of gas emanating from crude with reduction of reservoir pressure filled up rock pore spaces to the extent that oil flow was impeded. The important conclusion was this: Keep natural gas in solution in oil for greater ultimate production and for increased yield by natural flow.

The requirements for keeping gas in solution are: (1) A preservation of reservoir pressure and, hence (2), confinement of all gas possible in the reservoir until oil is extracted, (3) a reduction of oil rate from each well to the rate at which the gas-oil ratio remains constant, or at least as low as possible, (4) the shutting in of high gas-oil ratio wells, and (5) the injection of produced gas to maintain pressure throughout the reservoir. Such a program calls for unified operation and special modification of landowners' lease. Necessity for unification is alone enough to stop a program and it is a great credit to the industry that such plans as we do have in California have been effected.



FOOTAGE DRILLED
CALIFORNIA, 1938-1946

The fundamental basis of improved practice is preservation of reservoir pressure. This statement is based upon the technology of more than 25 years, plus actual application. It is true that there is not unanimous expert opinion on how pressure maintenance should be accomplished, and it is unfortunate that practical application is beset by so many difficulties, but there has been much progress.

● **Comparison of operations: Gas depletion vs gas conservation.** It is in order to compare a modern oil field with the performance of Signal Hill, which was at peak production more than 20 years ago.

The Wilmington oil field, discovered in 1936, could have been another Signal Hill—not so large, perhaps, but similar, in that it too was to some extent a so-called townlot field. By the time of its discovery, however, the art of petroleum engineering had developed to such a stage that operators realized that by restricting production in order to produce their wells at a lower gas-oil ratio, they would increase their ultimate recovery of oil. The relatively small blow of gas at Wilmington is evident from the following table:

Wilmington production and gas blow record.

Year	Avg. oil rate, bbl per day	Gas production, M cu ft per day	M cu ft per day gas blow	No. of wells end of year
1937	38,900	9,500	2,700	317
1938	93,600	53,100	26,300	565
1939	85,200	69,600	15,500	739
1940	82,500	71,000	12,500	916
1941	84,000	70,500	7,900	1,059
1942	92,200	85,600	2,400	1,095
1943	94,100	90,300	450	1,164
1944	100,900	104,900	137	1,335
1945	99,200	104,900	258	1,468
1946	110,000	113,000	122	1,649

The fact that some gas blow did take place, particularly in the early stages of development, is inevitable, because it takes time to design and construct plants, make contracts for the extraction of gasoline, and install gathering lines Of course, a large portion of the credit for the definite results achieved at Wilmington is due to the passage of the so-called gas conservation law by the State of California in 1929 and the Well Spacing Law in 1931. But the primary credit for the avoidance of waste of gas must be given to the increased realization by the operators that the restriction of high gas-oil ratio wells would increase their ultimate oil recovery.

PRESSURE MAINTENANCE

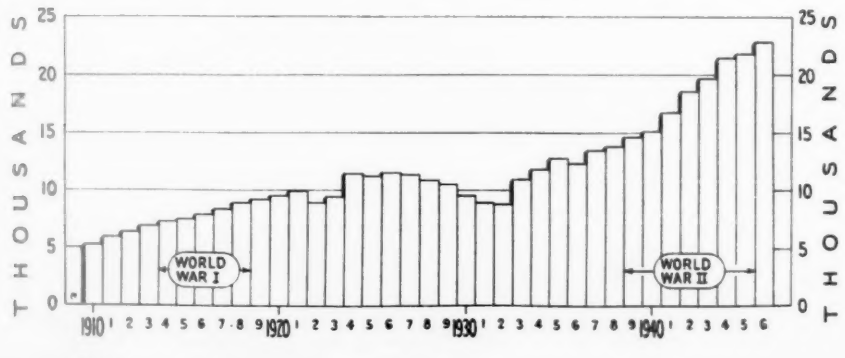
● **Definition of pressure maintenance.** The term "pressure maintenance" has been connected with gas injection into natural reservoirs that contain reserves of oil or condensate or both. This connection is appropriate because pressure maintenance is the name given to an oil producing program under which the natural pressure of the reservoir is kept as high as practicable by injecting gas. Pressure may not be kept constant, but the rate of decline is retarded.

● **Objects of pressure maintenance.** The practice has as its primary objective an increase in the ultimate yield of oil and condensates. In addition, the practice effects a decrease in oil production costs. These two objects are consistent, because lower costs reduce the minimum profitable production rate, and thereby postpone the abandonment of wells. This is an important feature when one realizes that in California at this time of record high production the average rate per oil well per day is only 37.3 bbl of oil (May, 1947, API).

● **The oil and gas sand.** The typical petroleum reservoir in California consists of an aggregate of minute pore spaces between grains of a sandy formation. The productive formation may be a hundred feet or more in thickness or, more likely, will be a series of sandy layers interspaced with impermeable shales.

As an example of the quantity in place, as oil occurs in oil sands, let us assume that 1 cu ft of sand contains about a gallon of oil. The yield, however, from this natural deposit would be much less.

PRODUCING WELLS—OIL AND GAS. CALIFORNIA, 1910 TO 1946



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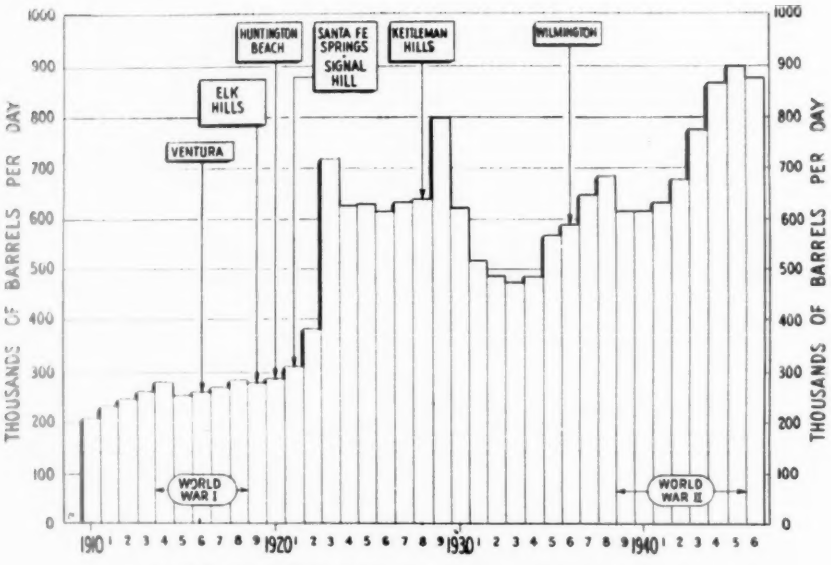
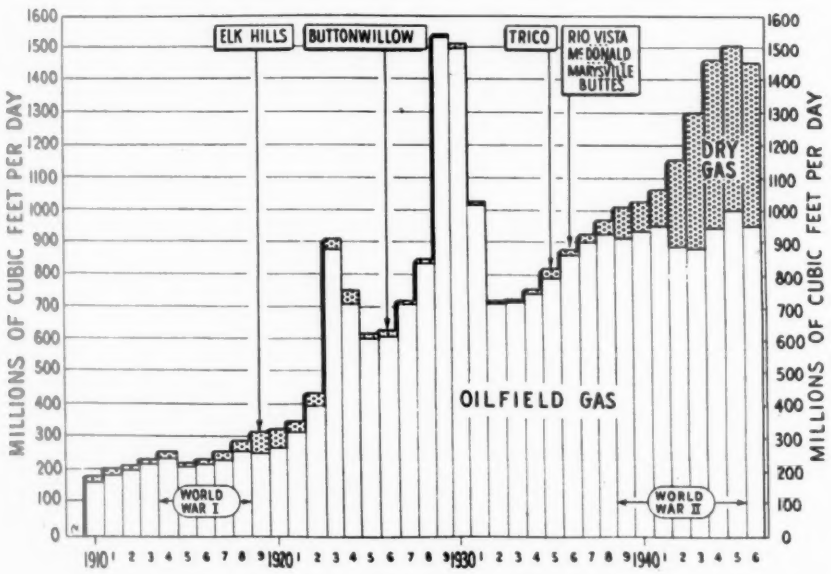


CRUDE OIL PRODUCTION. CALIFORNIA, 1910-1946



NATURAL GAS PRODUCTION. CALIFORNIA, 1910-1946

● **Yield of oil.** Some reasons for the fact that yield is less than the original content of the sand are:

1. Oil sticks to the formation.
2. Gas bubbles issuing from the oil upon reduction of pressure clog up the minute passageways between sand grains and obstruct the flow of oil.
3. Migration of oil is not uniform, leaving some portions of the oil sand undrained.
4. Encroaching edgewater follows a devious course, surrounding bodies of oil saturated sand, and entrapping oil therein.
5. Pressure, which provides the force to cause oil to flow, is exhausted before the oil is obtained.
6. The well rate declines to an unprofitable yield, and well is abandoned.
7. Physical defects in and around the wells reduce rates of production.
8. The oil gives up gas, and is cooled at the surface. Each of these changes causes a shrinkage.

The result is that estimated recovery of oil from California sands varies from a low of 15 per cent to a possible 40 per cent of oil in place, with higher recoveries dependent upon exceptional circumstances.

● **Analysis of application of pressure maintenance. The reservoir.** Now, suppose that we have an oil reservoir of some size, say, one estimated to contain a total of 132,736,000 bbl of oil, and 64,000,000,000 cu ft of gas, all in solution in the oil. The oil volume is in terms of liquid petroleum in place. The gas volume is in terms of standard conditions at the surface, nothwithstanding that all gas is in solution in the oil.

Many details would have to be correlated before one could arrive at an estimated recovery factor for oil and gas in a particular case, but for illustrative purposes suppose that this reservoir is partially developed. Production by the usual method indicates an ultimate yield of 25 per cent of the oil and 85 per cent of the gas, all in the course of some 30 to 40 years. In terms of products, this yield is 33,000,000 barrels of oil, and 54,400,000,000 cu ft of gas.

● **Reasons for pressure maintenance.** Engineers viewing this situation and fully informed of the difficulties of extracting oil from sands turn to pressure maintenance by gas injection, for the following specific reasons:

1. To keep oil thin in order to promote flow through sand.
2. To keep oil from increasing its tendency to cling to particles that constitute the oil reservoir.
3. To provide an expulsive force.
4. To prevent underground dissipation of oil resulting from migration into sands, formerly occupied by gas.
5. To control encroachment of edgewater.
6. To lower production costs.
7. To prevent condensation of gaseous products until they reach the surface, thus saving much product otherwise rendered irrecoverable.

When these advantages are appraised in terms of yield from the oil sands, the estimated increase is from 50 to 100 per cent more than by the natural depletion method. In addition, the estimated overall cost of production and field operation is reduced to such extent that a pressure maintenance program may be finally approved for this reason alone.

In the present example, suppose that engineers are very cautious and go on record for an increase in ultimate recovery of only one-third; that is, 33⅓ per cent more than 33,000,000 bbl, or 11,000,000 bbl. This increase is to be accomplished by building and operating a pressure maintenance plant for at least 20 years.

● **Pressure maintenance compared to depletion method.** This pressure maintenance plant is to cost $700,000, and well repairs and injection well expense will be $300,000—a total outlay of $1,000,000. As for building and operating the plant, the cost is more than covered by eliminating installation of pumping equipment and other expenses for the 20-year period. As for deferment of gas sales revenue, this is offset by a quicker realization of the oil revenue. Other factors are analyzed by the engineers with the results as set forth below.

Remember that a project such as has been analyzed promises an additional

Item	Depletion method	Pressure maintenance method
Oil yield, per cent of oil in place	25	33⅓
Gas yield, per cent of gas in place	85	85
Oil yield, bbl	33,000,000	44,000,000
Gas yield, M cu ft	54,400,000	54,400,000
Less M cu ft as follows:		
Allowance for gasoline plant fuel and shrinkage	6,000,000	6,000,000
Estimated field use	4,400,000	8,400,000
Estimated gas residue available for sale	44,000,000	40,000,000*
Btu available from all available products in terms of equivalent of gas. Oil at 6,090,000 Btu per bbl and gas at 1000 Btu per cu ft.		
Equivalent M cu ft	245,000,000	308,000,000

*When available for sale, this gas is under high pressure.

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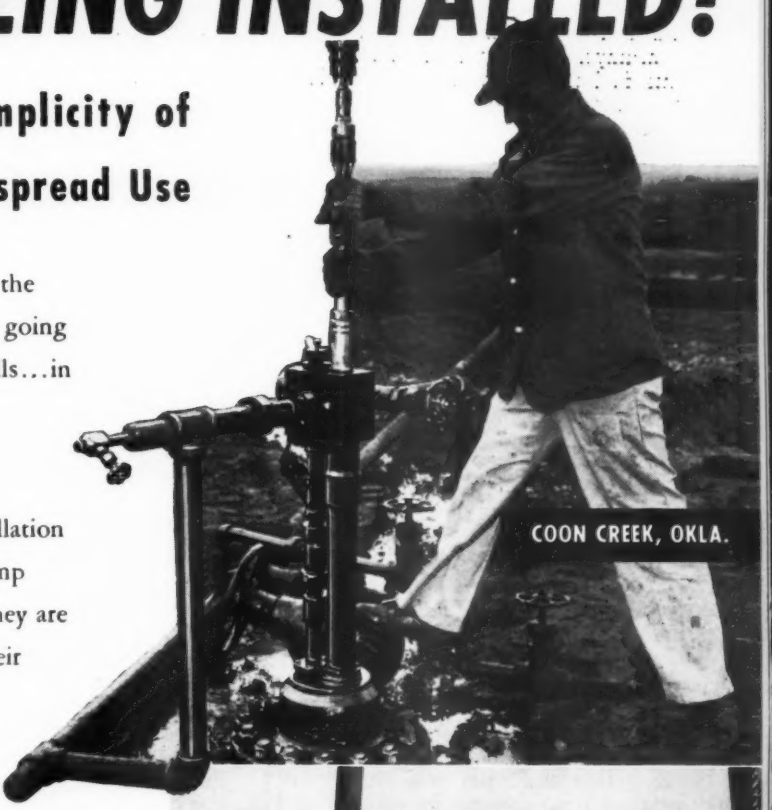
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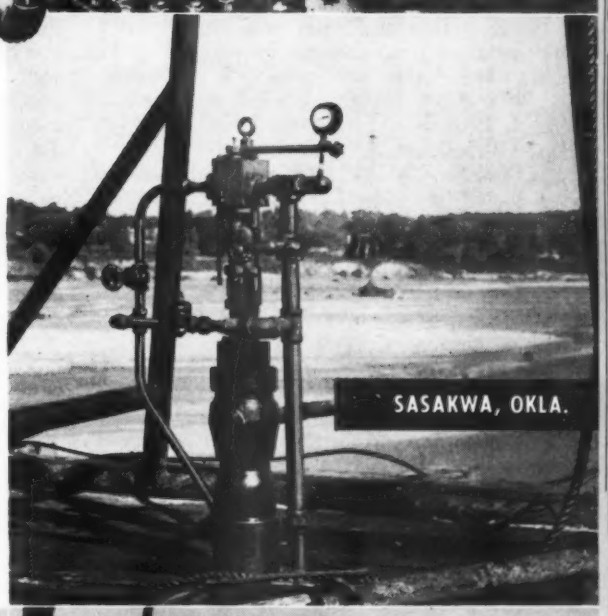
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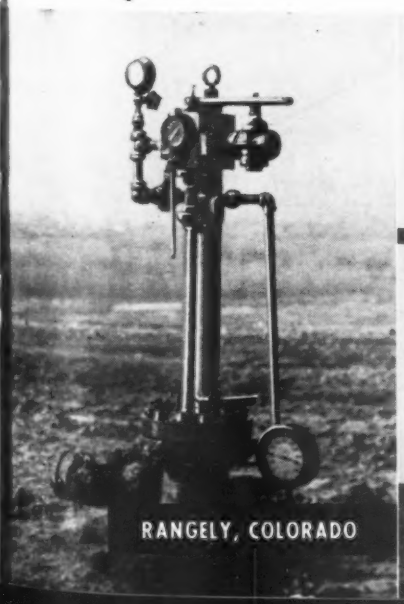
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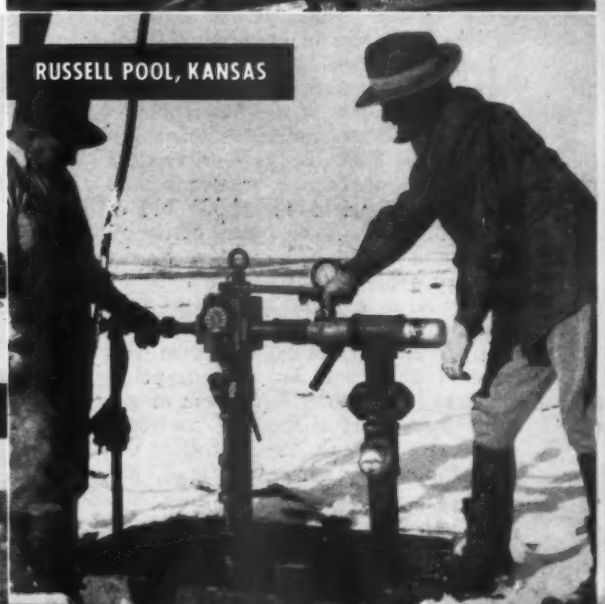
WEST TEXAS


RUSSELL POOL, KANSAS

11,000,000 bbl of oil for California supply—and this at a fuel use of only 4,000,000,000 cu ft more than otherwise would be required. This extra fuel amounts to less than 500 cu ft of gas consumption per bbl of yield. Surely this fuel is warranted. As for delayed gas production, who is to say that we shall not need the gas in the future as much as we do now? In fact, the release of pressure maintenance gas is already being written into estimates of the future.

● **Results of pressure control in California.** Pressure maintenance has been successful in the first essential—pressure decline has been retarded to a great extent. Results in all the reservoirs cannot be given because too little time has elapsed since gas injection began. The first major application, North Coles Levee, has sustained pressure to the extent that 23,000,000 bbl of oil have been produced in the last four and one-half years under pressure maintenance, with no drop in reservoir pressure since gas injection began. The original pressure at North Coles Levee was about 4000 psi and the first production was under the depletion method, which continued until the pressure dropped to about 3400 psi. The field has produced approximately 30,000,000 bbl and thus the first 7,000,000 bbl caused a reduction of about 600 psi, whereas the remaining production or 75 per cent has to date resulted in no pressure reduction.

The Canal field produced 3,600,000 bbl of oil, January 1, 1943, to January 1, 1946, with a pressure decline of only 170 psi. Prior to injection, the production of 1,000,000 bbl of oil and associated gas caused a decline of 130 psi. At Newhall-Potrero, where injection on full scale began in October, 1945, the pressure decline curve has been modified, indicating the same type of positive results as shown by the other two fields.

● **Cycling.** Cycling is a term applicable by common usage to the practice of conserving pressure in a condensate reservoir; that is, one like Paloma where a huge gas cap overlies the oil accumulation. Cycling is the generally accepted and recognized method of producing from a condensate reservoir. This method, which has been adopted at Paloma, is designed primarily to obtain liquefied hydrocarbons that would otherwise condense, become lodged in the sand interstices, and remain unrecoverable.

Engineers have calculated, with the aid of facts that were developed through a research project of the American Petroleum Institute and with other scientific data, that the present type of Paloma gas production, treatment, and injection will yield 44,000,000 bbl of gasoline, condensates, and black oil more than would be produced by the ordinary depletion method; that is, by production of gas and sale of the residue.

It is true that the cycling plant uses natural gas fuel, but consumption amounts to less than 4 per cent of gas throughput. Part of the fuel consumption represents only the immediate use of a future requirement; that is, gas returned to the reservoir is confined under high pressure, which will be available to ship the gas through transmission lines when the gas has served its purpose in the condensate field.

Successful continuance of the Paloma plan will not only result in the greater yield of condensates, as quoted, but also in more crude oil yield. Furthermore, a large proportion of the estimated natural gas reserve will be available for sale. The operators have backed their engineers' conclusion and recommendations with $6,000,000. Results of processing are as predicted by the engineers. This fact not only is a credit to their skill but also to the soundness of the basic data that have been developed under sponsorship of the API.

According to a survey published in proceedings of the API for 1945, there were in November, 1944, 37 gas cycling plants in the United States, 31 in Texas, 1 in California, and 5 in Louisiana. The combined processing capacity was 3,000,000,000 cu ft a day and production was 49,250 bbl a day of liquid petroleum products. The plants represent an installation of 95,325 hp.[1]

● **Pressure control by gas conservation.** Operators in some fields conserve pressure by control of the gas-oil ratio. In other words, instead of taking a large proportional part of the gas out of the reservoir and then replacing the gas, the well performance is so regulated that the gas-oil ratio is kept low. High ratio wells are shut in. Such fields do not appear in statistics as pressure maintenance fields because they do not inject gas, but the practice of keeping pressure from wasting has the same type of economic justification as the pressure maintenance method. The gas, thus confined, becomes available for use as fuel after the gas has served its purpose in oil production.

The first essential of pressure conservation is to keep gas in the reservoir. Oil cannot be produced, however, without some quantity of gas. Thus the object is to extract the minimum cubic feet of gas per barrel of oil. This object applies regardless of whether a gas injection plant is in operation.

Pressure conservation is practiced in varying degree. No field in California is expected to maintain pressure with no decline—the object is to adapt the practice to physical and economic conditions and do a reasonable job.

USE OF GAS IN OIL INDUSTRY

"Use" figures include gas "transformed into natural gasoline," a quantity customarily termed "shrinkage" and usually regarded as a deduction to be made from original supply, because the wet gas that contains liquefiable hydrocarbons is a raw product. This product yields gasoline, butane, propane, etc., each of which is as much of a liquid oil product as the crude oil itself. Thus, when wet vapors condense to make these liquids, the quantity of gas that condenses is not a use but a "transformation." Thus, the reported use is more than is actually consumed by whatever quantity is assignable to shrinkage.

R. L. Minckler[2] makes an estimated segregation of gas disposition covering 11 years, 1935-1945, inclusive. This division is in terms of total natural gas available. He divides utilization by oil companies in 1945, in terms of total supply, as follows:

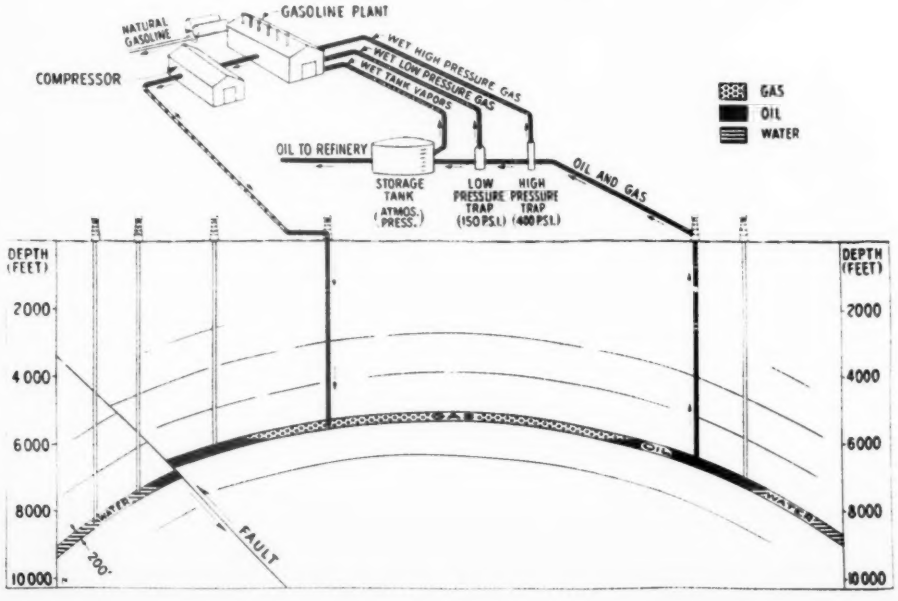
Transformed into natural gasoline, per cent	5
Oilfield fuel—boilers and gas engines—and natural gasoline plant fuel, per cent	18
Refinery use, per cent	11
Pipe line pump station fuel, per cent	3
Total, per cent	37

These percentages apply to a base of 535,514,000,000 cu ft, giving 198,000,000,000 cu ft as the quantity for the total 37 per cent. Thus, out of a reported

1. *API Drilling and Production Practice*, 1945, p. 117.

2. R. L. Minckler, Testimony in Case 4591, California Public Utilities Commission.

PRESSURE MAINTENANCE PROJECT, CALIFORNIA OIL FIELD



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According to a survey published in proceedings of the API for 1945, there were in November, 1944, 37 gas cycling plants in the United States, 31 in Texas, 1 in California, and 5 in Louisiana. The combined processing capacity was 3,000,000,000 cu ft a day and production was 49,250 bbl a day of liquid petroleum products. The plants represent an installation of 95,325 hp.[1]

● **Pressure control by gas conservation.** Operators in some fields conserve pressure by control of the gas-oil ratio. In other words, instead of taking a large proportional part of the gas out of the reservoir and then replacing the gas, the well performance is so regulated that the gas-oil ratio is kept low. High ratio wells are shut in. Such fields do not appear in statistics as pressure maintenance fields because they do not inject gas, but the practice of keeping pressure from wasting has the same type of economic justification as the pressure maintenance method. The gas, thus confined, becomes available for use as fuel after the gas has served its purpose in oil production.

The first essential of pressure conservation is to keep gas in the reservoir. Oil cannot be produced, however, without some quantity of gas. Thus the object is to extract the minimum cubic feet of gas per barrel of oil. This object applies regardless of whether a gas injection plant is in operation.

Pressure conservation is practiced in varying degree. No field in California is expected to maintain pressure with no decline—the object is to adapt the practice to physical and economic conditions and do a reasonable job.

USE OF GAS IN OIL INDUSTRY

"Use" figures include gas "transformed into natural gasoline," a quantity customarily termed "shrinkage" and usually regarded as a deduction to be made from original supply, because the wet gas that contains liquefiable hydrocarbons is a raw product. This product yields gasoline, butane, propane, etc., each of which is as much of a liquid oil product as the crude oil itself. Thus, when wet vapors condense to make these liquids, the quantity of gas that condenses is not a use but a "transformation." Thus, the reported use is more than is actually consumed by whatever quantity is assignable to shrinkage.

R. L. Minckler[2] makes an estimated segregation of gas disposition covering 11 years, 1935-1945, inclusive. This division is in terms of total natural gas available. He divides utilization by oil companies in 1945, in terms of total supply, as follows:

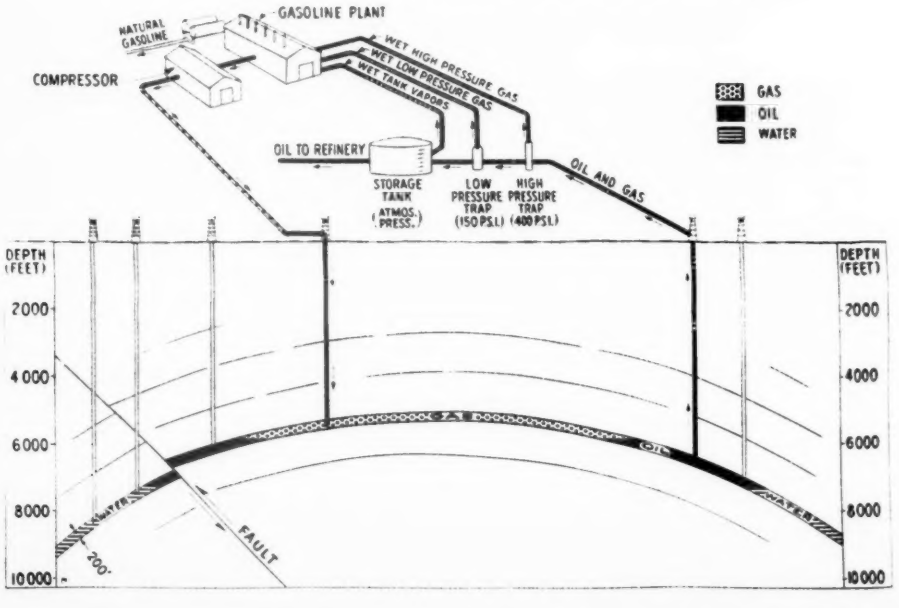
Transformed into natural gasoline, per cent	5
Oilfield fuel—boilers and gas engines—and natural gasoline plant fuel, per cent	18
Refinery use, per cent	11
Pipe line pump station fuel, per cent	3
Total, per cent	37

These percentages apply to a base of 535,514,000,000 cu ft, giving 198,000,000,000 cu ft as the quantity for the total 37 per cent. Thus, out of a reported

1. *API Drilling and Production Practice*, 1945, p. 117.

2. R. L. Minckler, Testimony in Case 4591, California Public Utilities Commission.

PRESSURE MAINTENANCE PROJECT, CALIFORNIA OIL FIELD



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total utilization of 198,000,000,000 cu ft, Minckler estimates that almost 27,000,000,000 cu ft was actually natural gasoline in the wet gas. This leaves 171,000,000,000 cu ft as oil industry use. In 1946 the reported oil industry utilization was 181,657,913,000 cu ft out of an available 521,154,098,000 cu ft, or 34.86 per cent. Using the same 5 per cent of production as representing natural gasoline in wet gas, the result is 26,000,000,000 cu ft, leaving 155,600,000,000 cu ft as oil industry use, or 15,400,000,000 cu ft less than in 1945. Minckler commented upon use of gas by the oil industry stating that, "there is no economic justification by any line of reasoning under which the oil company should sell gas at low prices and use fuel at high prices."

● **Transformation in natural gasoline and other products.** Liquid petroleum products from wet gas are a nuisance in a gas transmission line. Wet gas is, therefore, an undesirable commodity for the utilities to handle, and they ordinarily refuse to accept it when it contains any substantial proportion of condensable hydrocarbons.

Furthermore, these products, representing natural gasoline, propane, and butane, are much more valuable than the gas itself. The extraction of one gallon of such products reduces the quantity of gas available by approximately 30 cu ft. In liquid form the products now sell for about 16½ times what the equivalent gas itself could be sold for.

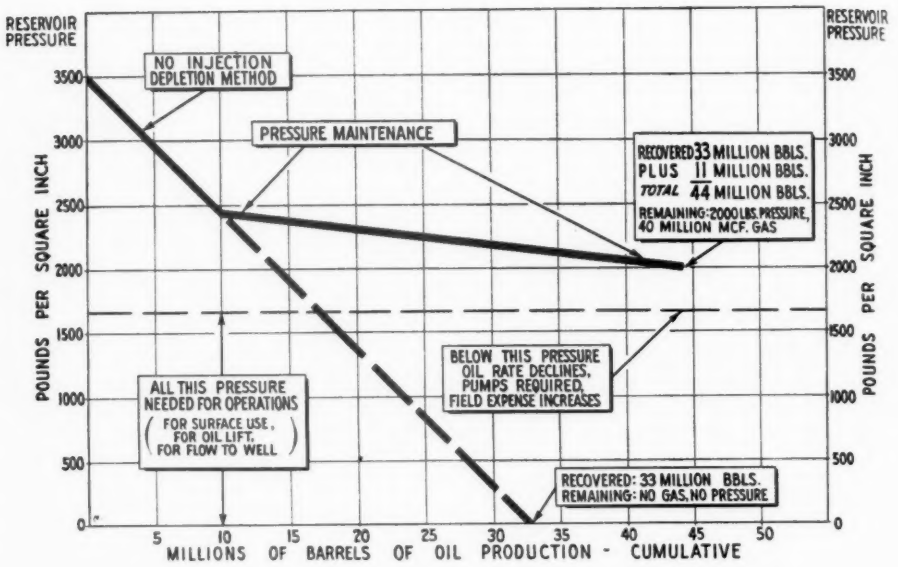
Such products as propane and butane in commercial blends are known as liquid petroleum gas, so-called because the liquid is readily convertible to a gas and used by thousands of persons for cooking, lighting, and refrigeration.

● **Oilfield use of natural gas for fuel.** The principal requirements for fuel in an oil field are for gas compression, oil well pumping, well drilling, and such miscellaneous needs as crude oil heating, for water separation, and ease of transmission, space heating for offices and shops, pumping oil through pipelines, and domestic use in oil field camps.

It would be merely time consuming to recite the circumstances connected with the choice of natural gas as a fuel for each of these oil field uses. The one reason is economics. Natural gas has been and is the lowest cost fuel, except in some cases where the electric motor and the diesel engine are especially adapted to operations.

Notwithstanding that natural gas is a cheap fuel, operators have done much more than is generally appreciated to reduce gas consumption. Millions of dollars have been invested in capital equipment to preserve pressure, and thus reduce the quantity of gas that must be compressed.

Natural gas compression is a requirement of long standing, and hence the suppliers of the engine and compressor units have developed a huge business. It was logical that the engine should be of the internal-combustion type because natural gas was the most convenient and the least expensive fuel.


RESERVOIR PRESSURE
POUNDS PER SQUARE INCH
3500
3000
2500
2000
1500
1000
500
0
NO INJECTION DEPLETION METHOD
PRESSURE MAINTENANCE
RECOVERED 33 MILLION BBLS.
PLUS 11 MILLION BBLS.
TOTAL 44 MILLION BBLS.
REMAINING: 2000 LBS. PRESSURE, 40 MILLION MCF. GAS
BELOW THIS PRESSURE OIL RATE DECLINES, PUMPS REQUIRED, FIELD EXPENSE INCREASES
ALL THIS PRESSURE NEEDED FOR OPERATIONS
(FOR SURFACE USE, FOR OIL LIFT, FOR FLOW TO WELL)
RECOVERED: 33 MILLION BBLS.
REMAINING: NO GAS, NO PRESSURE
5 10 15 20 25 30 35 40 45 50
MILLIONS OF BARRELS OF OIL PRODUCTION - CUMULATIVE

PRESSURE VS. PRODUCTION. TYPICAL CALIFORNIA CASE

The result is that in oil fields, gas fields, and on transmission systems the internal-combusion engine burning natural gas is in universal use as a prime mover for compressors. We may, therefore, expect such engines to be kept in use regardless of whatever others may be developed, especially when natural gas remains in such a choice position with respect to comparative fuel cost.

In pumping practice, operators select the form of power that is the most economical from standpoint of investment, operation, and maintenance. The largest proportion of pumping is done with natural gas internal-combustion engines, which are especially suitable for wells in remote places where electric power is either unavailable or would involve a prohibitive investment for extension of facilities.

Natural gas-burning oil field pumping engines would run on gasoline provided adjustments were made and the engine were equipped with a fuel tank and feed regulator. Such a change of fuel is out of the question because of increased cost of fuel itself, and the extra expense of fuel delivery and engine attendance, not to mention the cost of the changeover.

It is true that many pumping wells are powered by electric motors, but these have been chosen to fit special circumstances, in particular for installations of 10 hp or less. A change from gas engine to electricity involves the salvaging of the engine, the cost of a motor, the cost of transmission and transformers, and a relatively high power cost.

Power for drilling is supplied by steam, or by internal-combustion engines. The use of steam has become infrequent because of the more cumbersome equipment, water problems, and excessive use of fuel, whether it be oil or gas. The internal-combustion engines have been very successful. These engines are either standard gas engines, gasoline engines, or diesel type. There also is the electric powered rig.

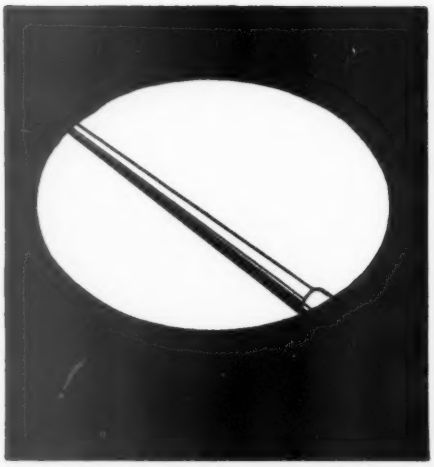
Gasoline plant engineers have also done much to reduce fuel consumption and increase the quantity of residue gas available for delivery to gas companies through the efficient use of tail gases such as condenser vapors, stabilizer overhead vapors, propane, and propane-butane vapors for which there is no market. A substantial proportion of these products is condensable and therefore undesirable from the utilities' viewpoint. The uses of such gases for plant fuel makes additional residue gas available to utilities.

● **Refinery use of natural gas for fuel.** Refinery engineers maintain close check on fuel consumption. They know not only what fuel is consumed, but what its heating value is and how much of each fuel was burned. This information indicates that a barrel of crude throughput requires about 600,000 Btu, it being understood that this figure varies with the plant and the processes employed.

Minckler estimates that 11 per cent of the supply of gas was consumed in refinery use in 1945, the quantity of gas represented being 58,800,000,000 cu ft. Using the same percentage for 1946 would give 57,300,000,000 cu ft. This consumption is about one-third of that which would be required if refineries did not utilize refinery gases, sludge, coke, and other kinds of fuel-providing material.

In other words, had refineries used natural gas exclusively in 1945 and 1946, the consumption would have been more than 170,000,000,000 cu ft each year instead of the less than 60,000,000,000 cu ft actually used according to Minckler.

● **Total use compared to total crude oil production.** Using the industry gas use figures as presented in this hearing (Case 4591), plus oil production statistics of the API, one may calculate the M cu ft of natural gas used per barrel



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After the Caliper has been run, the metal charts are photostated and each joint and coupling which has been surveyed is numbered, analyzed, and tabulated to show corrosion pit depth. The photostated charts and tabulations are supplemented with corrosion study data and a reliable interpretation of the general condition of the tubing. This material is then bound into a convenient easy-to-read Report on Tubing Corrosion Survey.

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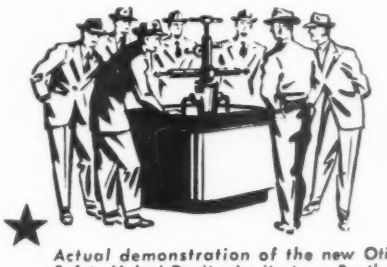

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of oil produced. Following are results for the last 12 years:

Year	M cu ft per bbl	Year	M cu ft per bbl	Year	M cu ft per bbl
1935	0.63	1939	0.57	1943	0.56
1936	0.66	1940	0.59	1944	0.59
1937	0.60	1941	0.55	1945	0.60
1938	0.60	1942	0.54	1946	0.58

When one considers that all our oil fields are aging and thus declining in the native reservoir energy that is available for production, that the so-called use includes much gas that has been transformed into gasoline, that increasing quantities of water must be lifted to obtain oil, that the trend of average depth is increasing, that refineries are making more products in more variety of useful form, all with somewhat less natural gas fuel per barrel of oil produced than was the case in previous years the conclusion is that increased fuel efficiency has been responsible. Further improvement will be made, but demand for energy will grow as reservoir pressures decline. In addition, these declining pressures cause the wet gas to contain more liquefiable hydrocarbons and, thus, a larger proportion of wet gas will be transformed into liquid products. My opinion is that the oil industry will do remarkably well not to exceed natural gas requirements in the ratio of 600 cu ft of gas per bbl of crude oil produced.

EXPLORATION

As the search for natural gas involves identically the same theory, technology, equipment, and personnel as the search for oil, this review not only covers dry gas exploration but general exploration.

A discovery, whether it be a new zone in a known field, an extension thereof, or a new structure close by such a field, or an entirely unrelated discovery made by a wildcat well cannot be immediately appraised. This fact accounts for the large annual revisions of estimated reserves. I have, therefore, selected long term histories to indicate results of exploration.

● **Recent results in gas exploration.** Geologist Graham B. Moody, in a professional paper published in Vol. 31, No. 6, June, 1947, *Bulletin* of the American Association of Petroleum Geologists, shows that 48 exploratory wells were drilled in California in 1946, primarily to find gas. This drilling resulted in four new fields, three new pools in areas close to known fields, and seven extensions of productive acreage. Thus, 14 out of 48 exploratory wells, or 29 per cent, were successful.

Up to September, 28 prospect wells were drilled during this year in search of gas in northern California. Not all were wildcats. Out of this total, seven wells resulted in commercial completions, but only one is in the discovery class.

None of these discoveries has caused much comment or excitement in the industry. It is too early to appraise the results in terms of gas reserves, but the total for all is not now thought to be large. Perhaps 100,000,000,000 to 150,000,000,000 cu ft would be a guess, which gives some order of magnitude to the aggregate of new gas fields in northern California discovered in 1946 and 1947.

As of September 1, 1947, there were two wildcat wells drilling in the San Francisco Bay region, and three geophysical crews were in the field. In July, the API reports four wells drilling in known gas fields.

● **Long term results in California.** A grand summary of the gas reserves situation is available. The first total is estimated in Dodge's report S-258, which gives 12.85 trillion cu ft as of January 1, 1941. Now, as of January 1, 1947, Huguenin estimates 11.84 trillion cu ft, a net reduction of only 1 trillion cu ft. Meanwhile, there was a production of 2.84 trillion cu ft in the six-year period. Thus, the state reserve decreased only 1 trillion cu ft, with a production of nearly three times that much. This does not mean that new fields added 2 trillion cu ft to reserves because a large part of the two trillion is an aggregate of adjustments in estimates, such as the upward revision of Rio Vista by 0.4 of a trillion cu ft as explained by Huguenin, but new fields, new zones, and extensions amount to an aggregate of important discovery as set forth in Table 1.

TABLE. 1. Additions to California natural gas reserves, January 1, 1941, to January 1, 1947.

(As presented to Public Utilities Commission in Case 4591)

	M cu ft
Calculation of additions to be accounted for	
Huguenin, Exhibit A-29, reserves as of January 1, 1947; all gas, available and unavailable	11,839,427,690
Add production 1941-1946:	
1941, Dodge, S-334, p. 29	388,934,639
1942, and to July 1, 1945, S-525	1,674,711,948
July 1, 1945 to January 1, 1946, S-525	257,682,579
1946, Exhibit A-29	514,741,614
Total 6 years' production	2,836,070,780
Total natural gas to account for	14,675,498,470
Reserves January 1, 1941, Dodge, S-258	12,853,151,687
Increase by discovery, revisions and corrections	1,822,346,783
Detail of discovery, January 1, 1941, to January 1, 1947	
	M cu ft
Total net addition to account for	1,822,346,783
Listed discoveries since January 1, 1941, arranged in order of appearance in the several exhibits.	
Field	Millions M cu ft
Vernalis	3.2
Aliso Canyon Seanon Zone	116.6
Antelope Hills	7.6
North Belridge Deep Zones	76.8
Helm	213.6
Jacalitos	15.0
Pleasant Valley	21.4
Raisin City	8.0
Riverdale	34.9
East Strand	4.8
Oak Canyon	29.0
Bowerbank	35.4
Chowchilla Area	20.0
Gill Ranch	37.9
Trico, new zones, etc.	190.0
Cymric	38.4
East Los Angeles	9.5
West Newport	11.6
El Segundo	11.0
Sub total	884.7
Some discoveries included in "re-estimates"	
Midway, Sunset, 27-B Pool (p. 140 of S-525)	62.7
Del Valle additions	36.7
Newhall-Potrero Deep Zone	85.9
Allowance for new fields privately appraised, not included in estimates	170.0
Total of tabulated items	1,240.0
Other net additions*	582.3
Total net additions accounted for	1,822.3

*Excludes many new fields of northern California. See p. 54 of S-525. Definitely excluded are Afton, Chico, Colusa, Corning, Dixon, Fairfield Knolls, Honker, Lodi, Moffatt, Ord Bend, Petaluma, Roberts Island, Suisun, Thornton.

Table 1 analyzes the changes between the estimate of January 1, 1941, and that of January 1, 1947, and shows the total gas reserve increase that is to be accounted for. This is 1,822,300,000,000 cu ft. Table 1 also lists new fields, new zones, and extensions that have been separately detailed in summaries of the quoted estimates, important similar additions that appear in the texts of those estimates, and an estimate I made for certain fields not included in the exhibits. Note that many fields of the San Francisco Bay area have not been estimated. Addition of the estimated reserves of the detailed discoveries yields a total of 1,240,000,000,000 cu ft, but it must be realized that many unlisted discoveries are absorbed in the "Other Net Additions," which amounts to 582,300,000,000 cu ft.

The data of Table 1 show that in the six years since January 1, 1941, during which term gas production was 2.84 trillion cu ft, we have found *at least* 1.24 trillion cu ft or probably more than the indicated 44 per cent of what we have produced. This statement is especially conservative when it is realized that discoveries of recent years are likely to be larger than is credited in the estimates. The annual discovery, as disclosed in Table 1, amounts to more than 200,000,000,000 cu ft.

● **Increasing difficulty of oil and gas findings.** It is only logical that the more new fields that are found leaves that many less to be discovered. The search for oil and gas has been prosecuted in California since about 1870, or for 80 years. The obvious fields were discovered long ago, the hidden but definite structures have been found by geophysics, and now we are stressing a search for stratigraphic traps. These are the most difficult to find. We have explored shallow depths and are now drilling deep, but as a search becomes more intense and the tests require deeper holes, the expense of geological exploration mounts. The tendency is to lessen the number of projects, but, nevertheless, Californians have maintained a remarkable record.

● **Long term review of oil and gas exploration in California.** In the ten years ending January 1, 1947, we have drilled 1697 wildcat wells. Of these, 1610 were dry holes and 87 were productive of oil or gas or both. This is a success ratio of 5 per cent or 1 well in 20. The resulting discoveries have not all been recognized as new fields, but however these wells may have been classified the important fact is that this drilling resulted in a considerable addition to our oil and gas reserves.

A record of annual oil reserve adjustments is presented in Table 2. The record is divided into two classes. One is for new fields and new pools, and the other is for revisions of former estimates and for extensions to known fields.

During the ten years 1937-1946, California produced 2,652,736,000 bbl of oil, or 90 per cent of our estimated reserve as of the beginning of the period. Our

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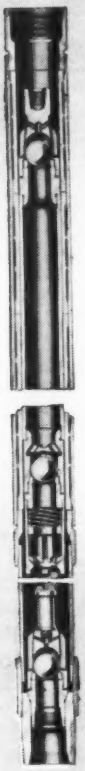

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TABLE 2. Ten-year record of changes in California oil reserves.

Thousands of barrels

Year	Revisions of previous estimates and extensions to known fields	Estimated reserves of new pools discovered during the year
1937	295,000	51,000
1938	240,370	135,000
1939	521,433	46,500
1940	— 17,090	very small
1941	243,278	18,750
1942	115,830	5,195
1943	408,993	16,170
1944	242,575	76,925
1945	328,586	63,254
1946	276,787	13,876
Total 10 yr..	2,655,762	426,670

Estimated by Committee on Petroleum Reserves, American Petroleum Institute.

Data from *Petroleum Data Book*, First Edition, 1947, Petroleum Engineer Publishing Company, Dallas, Texas. See Sec. C-11.

reserves are now more than they were then. They stand at 3,293,491,000 bbl as of January 1, 1947. It is obvious that revisions and extensions are the most important. Of the total of 3,000,000,000 bbl added in ten years, only a little over 13 per cent was assigned to new fields during the years in which the discoveries were made. Thus, the importance of a discovery is not immediately known. In Signal Hill, for example, 26 years after discovery, deeper zones are still being found.

In addition, oil operators through research, technology, engineering, and experience are learning more about the appraisal of oil in place and the extraction of that oil. Through such improvements as are illustrated by pressure maintenance, we are increasing the recovery factor; that is, improved methods result in a greater proportional yield of the oil deposit. If, for example, a discovery is rated at a reserve of 100,000,000 bbl, this estimate may have been based upon a recovery of 25 per cent of a calculated 400,000,000 bbl of oil originally contained in the sands. Upon application of a pressure maintenance system, the estimated recovery may be raised to 40 per cent, with resulting anticipated reserves of 160,000,000 bbl. The increase of 60,000,000 bbl becomes a part of the "Revision of Previous Estimates" and represents a real addition to estimated reserves.

It is appropriate to note, however, that a discovery of an entirely new field is a more satisfactory addition to reserves than a revision of an estimate of an old field. It is the finding of new fields that provides for continuity of supply.

● **New fields in California, a 10-year history.** The cumulative effect of the many discoveries in California represents an achievement of considerably more significance than is generally realized. A list of new fields in California, which does not include extensions and deeper zone discoveries with the exception of the 27-B Pool in Buena Vista Hills, is shown in Table 3.

The total of all these fields, that is, 35 fields with 1010 wells producing 92,026 bbl a day, is one practical summation of the discovery effort of years 1940 to 1945 inclusive, plus all drilling done in these fields since the respective discovery dates. The total of 92,026 bbl a day for the group of new fields represents 10 per cent of the California daily oil output.

In conclusion, our exploratory effort of the last six years has not been spectacular but it has been effective.

1. Reserves of oil and gas have been maintained at a high level, and in a remarkable state of productivity.

2. California oil operators met the war demand for oil and gas in excellent fashion.

3. Postwar demand is being cared for despite shortages of material and the state is producing oil at the maximum of its history.

● **California discoveries of 1946.** As for the year 1946, including the gas well statistics already quoted, the data show 269 wildcat wells drilled in California with 15 productive, a ratio of one success in 18 tries, or 5½ per cent. Discoveries made by the productive wells, with data so far available, have been appraised in the API reserves estimates at 13,876,000 bbl. These wells are not necessarily correlative with the wells of the statistics.

Moody lists 18 oil and gas wells as "Successful New Field Wildcats" in 1946, but he states that the number of "New Field Wildcat Wells" was 211, giving a success ratio of nearly 1 in 12. He also states that the total number of exploratory oil and gas wells in California in 1946, regardless of whether new field wildcats, new pool wildcats, deeper pool tests, shallower pool tests, or outposts, was 366 and the number of successes was 70, giving a ratio of a little more than 1 in 5 or 19.1 per cent.

● **Current California exploration.** In addition to work being conducted in the San Francisco Bay region, 37 other wildcat wells are drilling; 19 in the San Joaquin Valley, and 18 in southern California. In addition, six geophysical crews are at work in the San Joaquin Valley.

The API makes a monthly report of exploratory wells including wildcats. The 1947 record is in Table 4.

The remarkable feature of this table is the consistency with which more than 40 exploratory wells are kept drilling. A decrease appears in June and July, and similar data were not available for August, but for September I learn that 39 wells are drilling, showing that the rate is being maintained.

Note the abandonments each month. Despite this discouragement, an equal number of new rigs are up to continue the search. If these abandonments were appraised in terms of expense, the figures for some single wells would run into several hundreds of thousands of dollars. One such abandonment, for example, is Pacific Western's U. S. Royalties wildcat. This well was drilled to 16,668 ft in search of a sand known to be productive in Kern County. The sand was found but was unproductive. The well was the deepest in the world until recently surpassed. The cost of this well and the expense associated with the exploration ran close to $1,000,000. When one reviews California statistics with this costly background in mind he should realize that the oil industry in this state is conducting a stupendous campaign for more oil. In seven months of 1947, 166 tests have been drilled and 14 have been productive, giving a success factor of one in twelve. The degree of success is another matter and judgment must await further development. Apparently there have been several fairly important discoveries in 1947. These are:

Deep zone in Signal Hill, by Shell Oil Company, Inc.

Belgian Anticline of North Midway, by The Texas Company.

New Laundale deep field, by Seaboard Oil Company.

Las Flores of Orcutt area, by Sunray Oil Company.

Montalvo of Ventura area, by Standard Oil Company.

Middle Dome of Kettleman Hills, by Standard Oil Company.

Bacon Hills of Belridge area, by Seaboard Oil Company. ★★★

TABLE 3. List of new oil fields, discovered 1940-1945, inclusive, in California, with number of producing wells and daily average barrels of oil production July 1947.

Field	Discovery date	— July 1947 — Prod. wells	Daily Prodn.
Del Valle	1940	93*	8,412
Pyramid Hills	1940	21*	251
Blackwell's Corner	1941	28	172
Helm	1941	67	3,995
Oak Canyon	1941	17	1,590
Jacalitos	1941	76	4,677
Raisin City	1941	40	2,650
Riverdale	1941	60	4,222
Turnbull Canyon	1941	5*	109
Union Avenue	1941	3	253
Buena Park	1942	2*	44
Holser Canyon	1942	1*	30
Williams	1942	29	1,311
Zaca	1942	2	413
Bradley Canyon	1943	0*	0
Burrel	1943	1*	15
East Strand	1943	7	581
Lanare	1943	33	1,773
McClung	1943	1*	16
Pleasant Valley	1943	25	4,263
Tejon	1943	75	3,461
Ant Hill	1944	36	1,437
Antelope Hills	1944	0	0*
Bellevue	1944	3*	303
27-B Pool	1944	145*	35,086
Gosford	1944	2*	16
Gould Hills	1944	no data	
Hasley Canyon	1944	1*	10
Race Track Hill	1944	32	2,205
Sheep Springs	1944	4*	554
McDonald Anticline	1945	6*	70
Newport (N)	1945	158	7,017
Rosedale	1945	4	85
Santiago	1945	31*	6,957*
Sansinena	1945	2*	48
Total—35 fields		1010	92,026

List of fields and dates from L. E. Porter in AIME Statistics of Oil and Gas Development, 1946.

Producing wells and production from API monthly "Summary California Oilfield Operations."

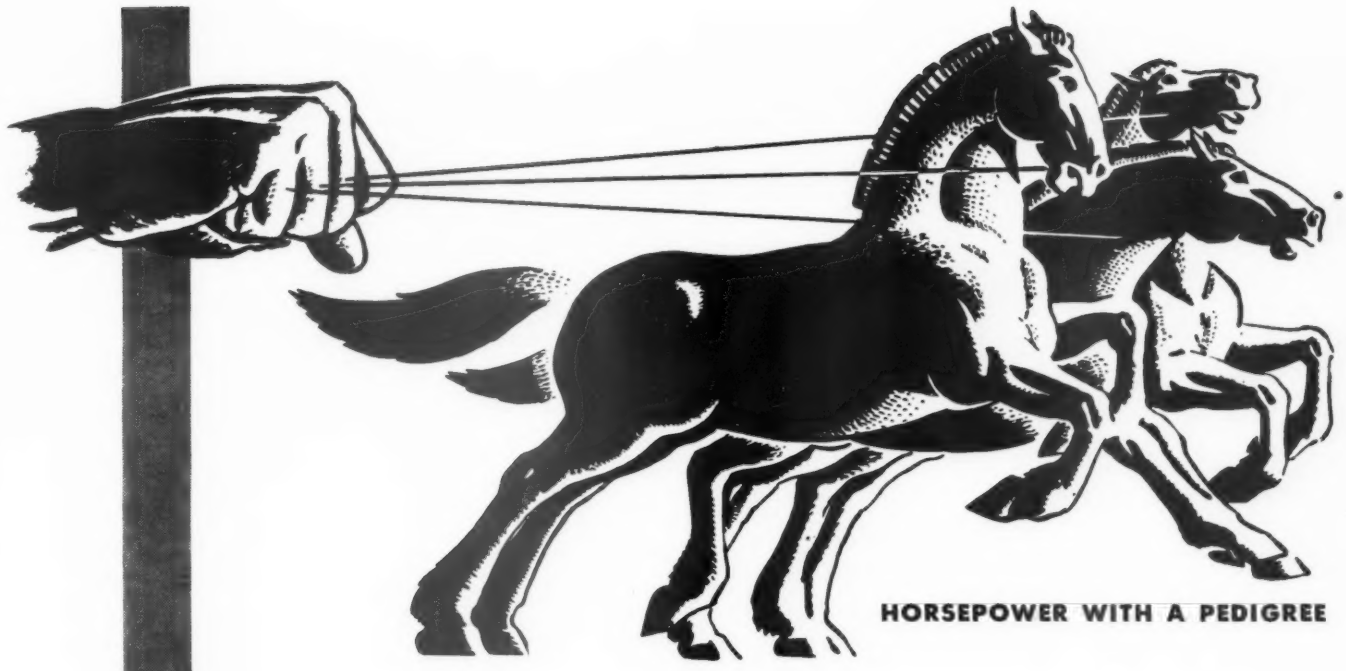
*From Conservation Committee of California Oil Producers.

(N)—Not listed by Porter as a new field, in 1945, but new developments are now important.

TABLE 4. California exploratory wells, 1947.

Month	New rigs up	Active drilling	Abandoned
January	27	48	19
February	21	48	20
March	22	40	28
April	21	41	20
May	27	44	23
June	19	29	25
July	18	29	20

Data from API monthly "Summary of California Oilfield Operations."



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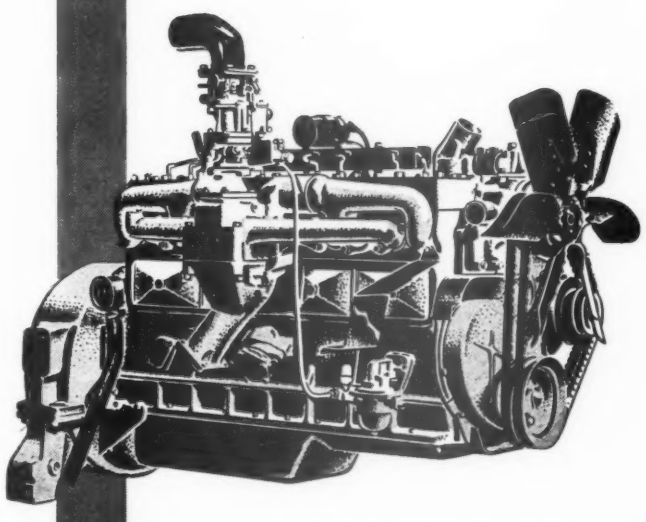

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Locating pipe lines and leaks by electronics

By J. L. CASSINGHAM, Field Engineer,
The Goldak Company

Modern pipe locator is a light weight, easily operated, electronic instrument. Above illustration shows the 'on-handle' method of operation, which is used when location of pipe is only vaguely known.

"DITCHING machine snaps phone cable." Frequently these words head news items in our daily papers. The story goes on to state that several hundred, or thousand, homes were left without telephone service for several hours until temporary repairs could be made.

EXCLUSIVE

Oil lines, gas mains, water pipes, are ever-present obstacles to construction crews laying new pipe lines. Sometimes their presence is never even suspected—blueprints have been lost or become inaccurate due to changing landmarks. Often no record at all was kept when the pipes were first laid.

One West Coast construction foreman, commenting on his difficulties, said that at least he was better off than if he were on the East Coast where they had been laying pipes and losing them for many years longer. Also, he didn't ever have the frozen ground that Easterners often had to contend with in the winter months.

In this day of rapid development and construction, with labor and material costs still mounting, it becomes increasingly necessary to avoid costly delays. A severed pipe line is really a double loss as men and materials that should be used to progress with the construction program, have to be sidetracked to make the necessary repairs.

During the war, the entire water supply of an army base on one of the Hawaiian Islands was lost when a bulldozer, cutting a road on the side of a hill, severed the water main leading from a huge tank on top of the hill. All water in the tank ran down into the base before the shut-off valves could be reached. Not only was the water lost, but the base was flooded and much damage was done to stores and supplies.

This could have been prevented by the use of a modern, electronic pipe locator. These instruments, many of which are now being used by various utility and construction companies, have been developed during the last several years to a point where they are considered an absolute necessity by field engineers and foremen.

No longer is it necessary to probe for a lost pipe by driving a steel bar into the ground, often many times, until the pipe is hit. The writer recently demonstrated a locator in Montrose, California. The "problem" was to find a valve that had been lost for 15 years.

"It should be about here," said the foreman pointing to an area on the pavement. In the small radius he indicated were numerous round holes where a steel bar had been driven in search of the valve. A few rapid passes of the instrument over the area and a sudden squeal sounded in the head set. The spot was marked and a laborer fell to work with a pick. His second swing struck the valve cover just two inches below the pavement and right between two holes made by the steel bar!

It takes but a few minutes to assemble and adjust the pipe locator for use. This done, the workman simply walks ahead of the ditching machine or bulldozer, his eyes on the meter and his headphones in place on his ears. Whenever he passes over a pipe or cable a sharp signal sounds in the phones and the needle on the meter gives a strong response. He then simply marks the pavement with a piece of chalk as a warning to the equipment behind him.

The pipe locator is a moderately priced instrument consisting of a transmitting unit and a receiver or detector unit. The transmitter energizes the earth beneath it, and any pipe in the ground, being a much better conductor than the earth, will set up a strong radiation that will be picked up by the receiver. The loops in the instrument are so constructed that they work on the principle of a direction finder so that the maximum signal is achieved when the antenna is directly over the pipe. This sharp "peak" signal is necessary not only for locating the pipe within a limit of a few inches, but also in cases where there are two or more pipes close together running parallel to each other. If this is the situation, a peak signal occurs when each pipe is crossed. (See Fig. 1).

In some metropolitan areas, where there are often several pipes at different depths and running in different directions, the operator will find it necessary to use the direct connection method in tracing a pipe. Here a lead from the transmitter is attached to the pipe and the pipe energized by conduction rather than by induction.

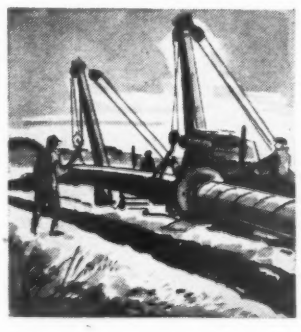
There are two main procedures used in surveying an area for pipes and cables. In event the location of the sought after pipe is only vaguely known, the units are mounted on handles, and the instrument operated as an induction balance. In this procedure, the transmitter loop is adjusted by a special control until a silence or null is achieved. In doing this, the operator has balanced the units so that no signal is picked up either through the air or from the ground itself. When a pipe or cable is crossed, the balance is disturbed and a sharp signal occurs. Crossing and recrossing the pipe once or twice will determine the general direction in which the pipe runs and the units can then be used as a direction finder as indicated.

Here the units are detached from the handle, the transmitter placed on the ground over the pipe in a position gen-

The Author

J. L. Cassingham, field engineer, has been associated with The Goldak Company for the past 15 years with the exception of three and a half years in the Army Air Forces. His wide field experience consulting with public utilities, oil companies and other users of pipe locating and leak detecting equipment, places him in a position to speak authoritatively on such equipment and the problems involved.

What is BARRETT'S PROTECTION SYSTEM?



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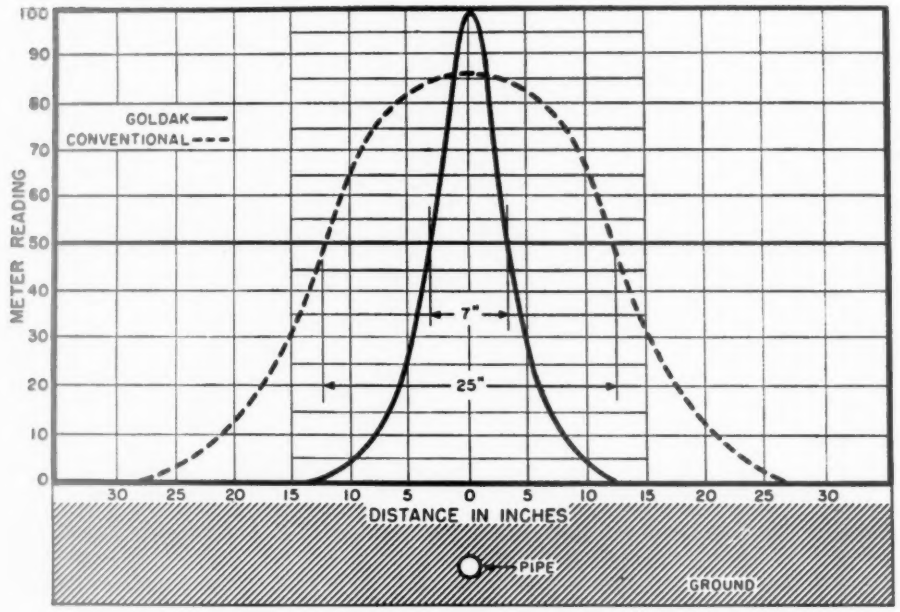


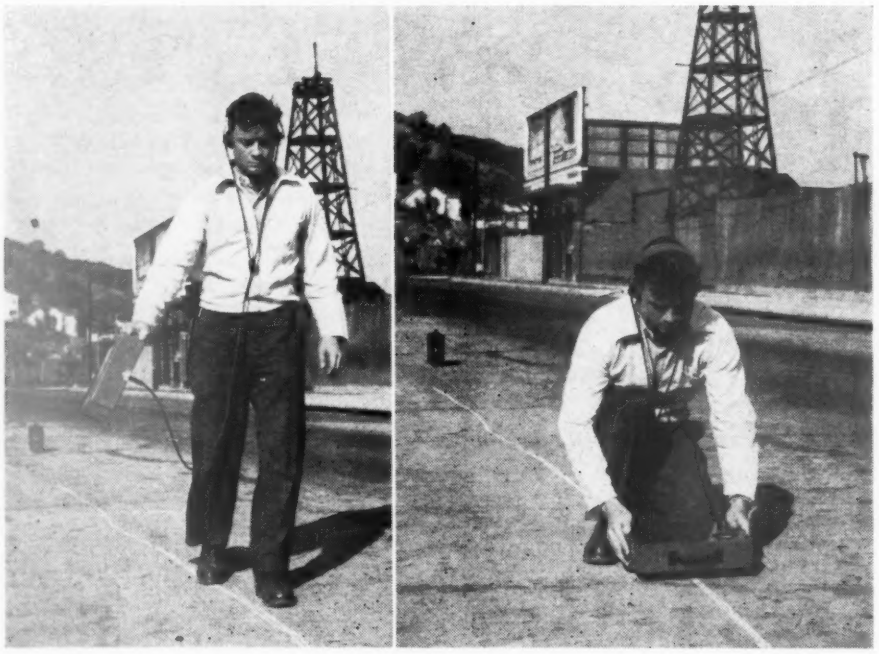


FIG. 1. Top, curve shows sharpness of signal that is obtained by present day locators when a buried pipe is crossed.

FIG. 2. Above, the pipe has been located and is being traced on out. The transmitter (rear) has been placed over the pipe to energize it.

FIG. 3. To center the pipe exactly, the receiver is held as shown above at right. The 'null' occurs when the pipe below exactly bisects the unit.

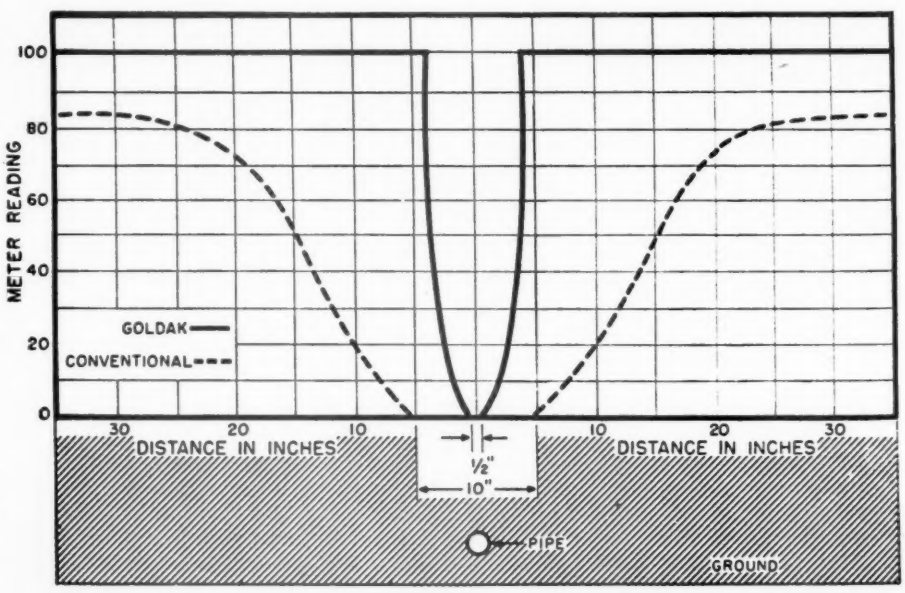
FIG. 4. In the centering operation, right, the 'null' is very abrupt and narrow. As is shown in the graph, the null is narrower than the pipe itself, assuring extreme accuracy.

erally parallel to it. The receiver is carried in the hand along the general path of the pipe as was determined when the instrument was operated on handles. The receiver is swung in an arc as the operator advances. (See Fig. 2). When the unit passes directly over the pipe, the sharp signal will be heard. The intensity will decrease as the distance from the transmitter widens making it necessary to turn up the receiver power bit by bit until, when the instrument is at maximum power, a distance of up to 250 ft or more will have been covered. Here the transmitter is brought up, placed once more over the pipe, and the routine continued until the pipe has been followed the necessary distance.

Occasionally it will be necessary to center the pipe even more sharply than can be done in the procedure just described. This can be done by holding the receiver over the pipe, close to the ground and horizontal to it, and at a distance of 20 or 30 ft from the transmitter. (See Fig. 3). In this position a strong, continuous signal will be heard. The receiver is then shifted slightly back and forth. When the pipe below *exactly bisects* the unit a dead silence results. (See Fig. 4). This silent area or null is always narrower than the pipe itself.

The same principle can also be used to measure the depth of the pipe. Here the receiver is held at a 45-deg angle as shown in Fig. 5, and moved slowly away from the line of the pipe. At a certain distance another null will occur. This distance is equal to the depth of the pipe. (See Fig. 6). The accuracy of this operation is affected by the refraction of the radiation as it passes from the air into the ground, and also by any other pipes that may be nearby.

Up to this point, nothing has been said about the pipe locator's companion instrument, the leak detector. Sometimes only a part of the task has been completed with the location of a pipe. There often is a leak to find also. Usually this is not so simple as it sounds. Often a long stretch of the pipe lies buried, and to uncover it all in search of a leak



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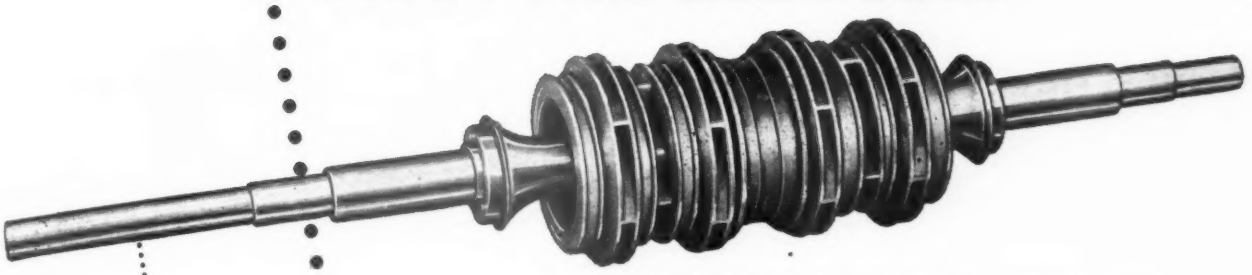
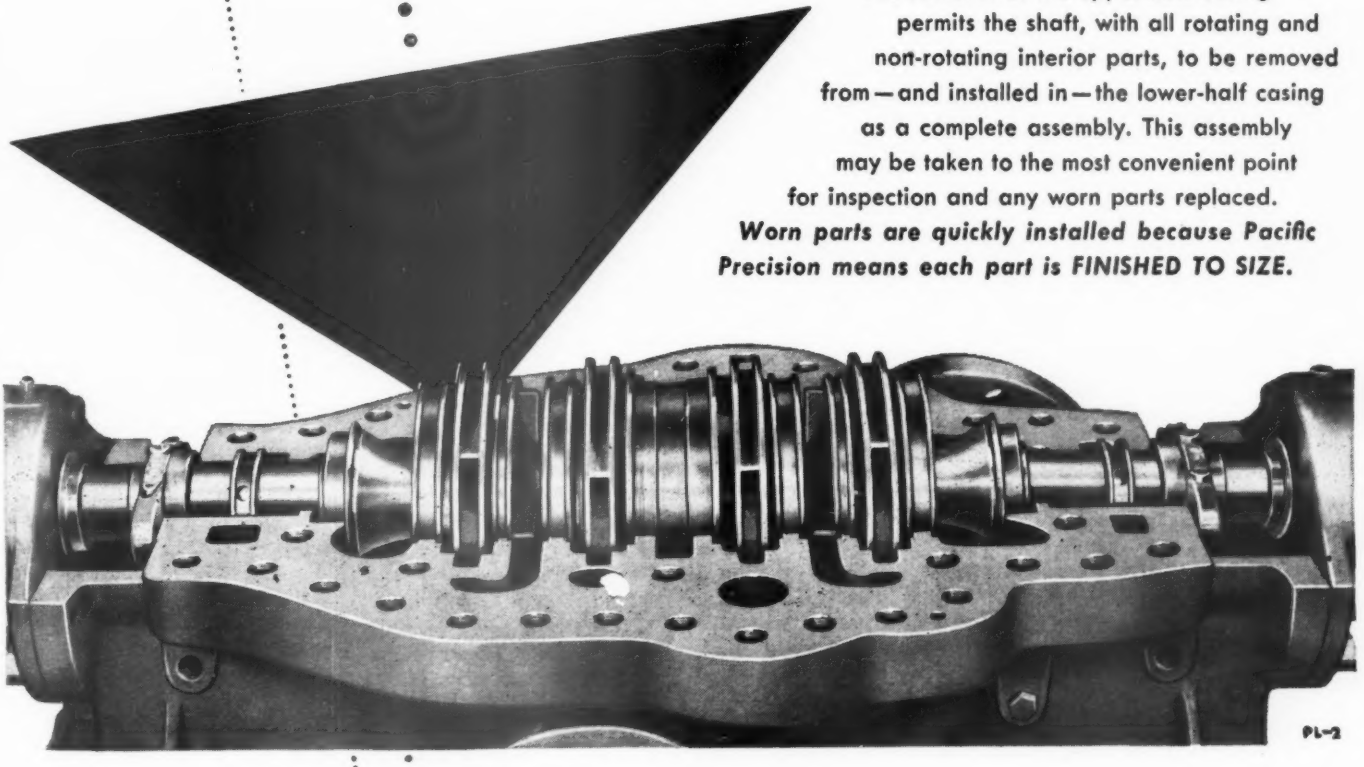


Mechanical equipment requires a certain amount of inspection and maintenance to prevent major troubles. When inspection is simple, it is most likely to be made.

PACIFIC TYPE F PIPE LINE PUMPS ARE EASY TO INSPECT AND MAINTAIN IN THEIR MOST EFFICIENT OPERATING CONDITION because they may be dismantled and reassembled quickly with the minimum of labor.

The removal of the upper-half casing permits the shaft, with all rotating and non-rotating interior parts, to be removed from—and installed in—the lower-half casing as a complete assembly. This assembly may be taken to the most convenient point for inspection and any worn parts replaced. ***Worn parts are quickly installed because Pacific Precision means each part is FINISHED TO SIZE.***



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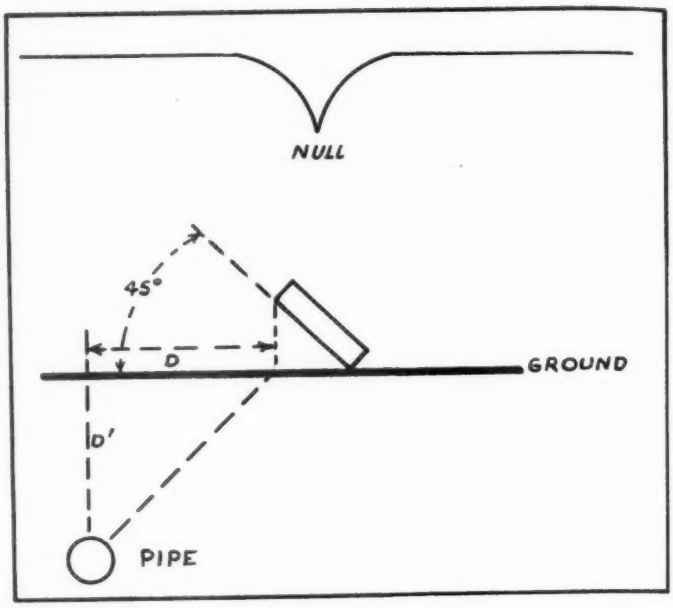


FIG. 5. Holding the receiver at an angle of 45 deg, the operator, above, moves out from the line of the pipe. The null occurs when the unit has been moved a distance equal to the depth of the pipe.

FIG. 6. The diagram, upper right, shows the principle used to determine pipe depths. A device built into the instrument gives the 45 deg angle.

FIG. 7. Right, the leak detector measures intensity of vibrations set up by leak in pipe. The point of greatest intensity shows the location of the leak.

would be impossible. If it is a water leak, the water will frequently flow along the pipe or just beneath the pavement before it rises to the surface. Sometimes it does not appear on the surface at all.

The leak detector has been devised to make just such a problem simple. Naturally, a fluid under pressure, escaping from a hole or crack in a pipe makes a noise and thus sets up vibrations. By means of a special vibration pickup, this slight noise is detected and highly amplified. The point at which the intensity is greatest shows the location of the leak. Fig. 7 shows the instrument being used to search for a leak beneath the pavement.

Of course the detector must embody several features to accomplish this effectively. The instrument must be sensitive to a wide range of leak vibration frequencies and yet eliminate traffic noises, and other sounds that are encountered. It must be light in weight and easily manipulated; and it must be easily controllable so that the full range of leak frequencies and intensities can be covered quickly.

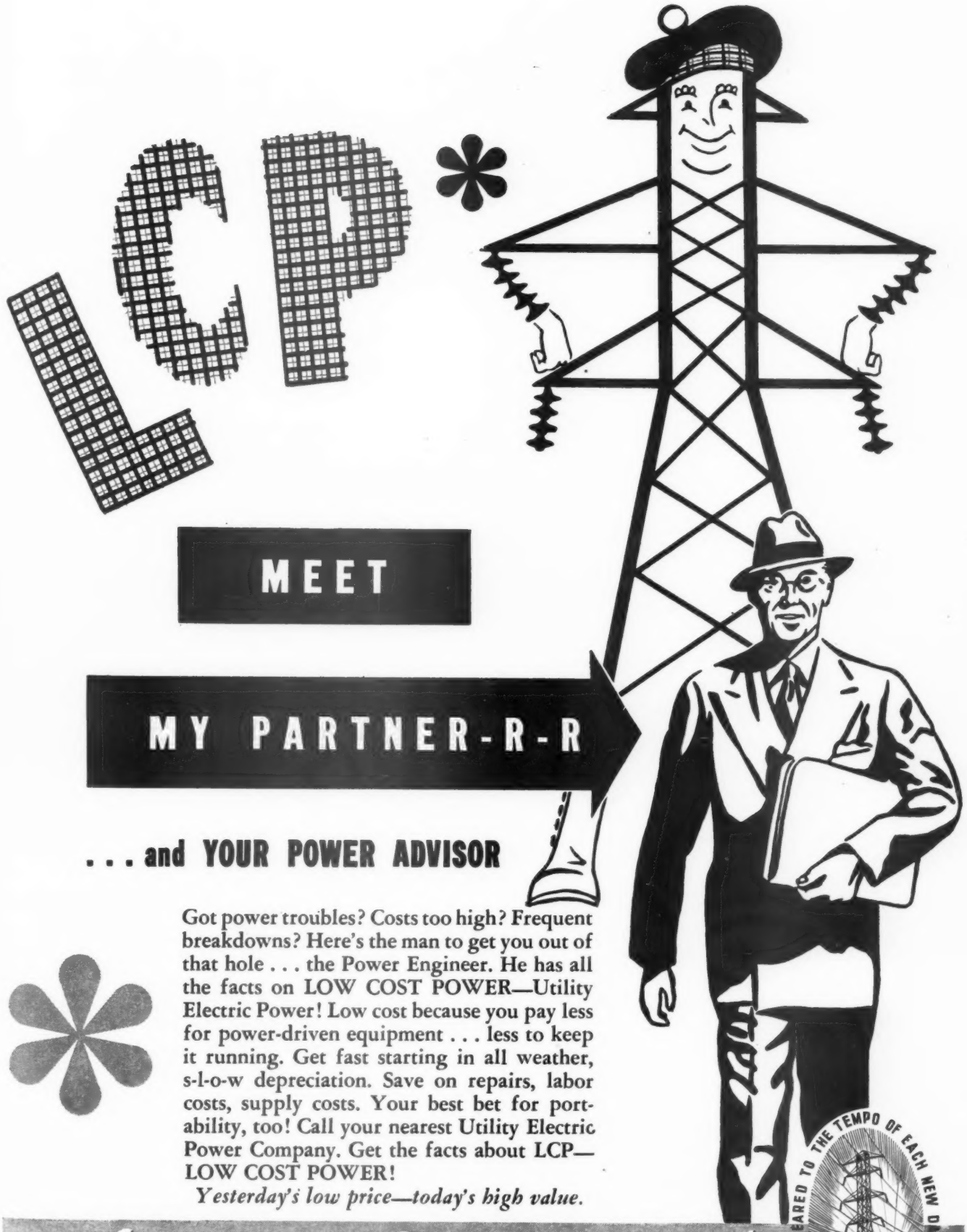
Another totally different application of the leak detector is worth mentioning here. Often, in order to avoid excavating, a drill will be forced under the pavement from one side of a street to the other. Occasionally, as any foreman familiar with such jobs knows, the drill will fail to appear on the opposite side of the street even though the required length has been run out. The drill has, of course, been deflected. With the leak detector, the course of the drill can be detected by simply listening as it bites through the earth. The pipe locator can also be used to trace the drill out, exactly as a pipe would be traced.

The possible saving in time, money, and labor cannot be overemphasized. Obviously, one costly repair of an important pipe line could pay for several pipe locators. All too frequently damage is done before the need for an instrument is realized.

One large public utility company in Southern California now has in use more than 400 pipe locators, another company in the same area has nearly as many. Both maintain shops where their instruments are repaired and kept tuned to give maximum efficiency on the job. That their worth is appreciated is proved by the fact that the men who use them argue over who is to get the latest lightweight models to use.

There are certain conditions that the pipe locator cannot, at present, cope with. Terra cotta pipe for example. Unless a steel tape can be slid through such a pipe, the locator cannot pick it up. Sometimes extremely poor ground conditions make the instrument's task most difficult. Highly mineralized ground, numerous criss-crossing cables and pipes, overhead wires, etc., tend to reduce the machine's effectiveness. These problems are constantly being tackled, however. New circuits are being devised and tested and new improvements are introduced yearly.

There is one in particular that the writer doubts will be overcome very soon. He was recently called upon to demonstrate an instrument for a Los Angeles concern about to start a large expansion program. The pipe selected for the test was buried a foot or two beneath pavement—reinforced with closely woven steel mesh! ★★★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Engineering air compressor installation*

PART 1

Planning, selecting and installing the compressor air plant.

In order to obtain the benefits and the advantages of compressed air, planning is essential. To achieve the savings and results expected, care must be exercised in the selection of the quipment, in its installation, and in laying out the distribution system. This article will suggest important questions to consider in planning the compressed air plant. It will also discuss low pressure air, its causes, effects, and remedies.

A compressed air plant (Fig. 1) consists of one or more compressors, each with the necessary driver, control or regulation, intake air filter, aftercooler, air receiver, and interconnecting piping, together with a distribution system to carry the air to points of use.

● **Objective of installation.** The object of installing a compressed air plant is to provide a sufficient quantity of air to the work at sufficient pressure for efficient operation.

Before attempting to determine the amount of compressed air necessary, a thorough study should be made to provide for the use of air power in all applications for which it is suitable. The importance of this study in approaching the problem of installing the compressed air plant is obvious because it will anticipate possible future needs as well as present ones.

The information obtained from the study previously referred to will then become basic in approaching the problem of engineering the compressed air installation in any particular plant. In working out an installation, a series of analyses is recommended. These include:

1. Necessary compressor capacity.
2. Number of compressor units.
3. Location of compressor units.
4. Regulation of compressed air plant.
5. Compressed air distribution system.

● **Necessary compressor capacity.** The proper capacity to install is, of course, a vital question, requiring careful analysis. A study of air-operated devices in a typical plant will show that many of these devices operate almost continuously but there are others that operate infrequently but require a relatively large air supply when in use. It will also be discovered that the actual amount of air used by the individual device will vary greatly in different applications.

The first suggestion is, therefore, that the average air consumption of air-operated tools be ascertained. This may be obtained from manufacturers' literature or may be closely approximated by actual test. Care must be taken not to assume that all air-operated devices consume their maximum under all conditions, as otherwise a false plant size will be developed. Therefore, the load factor of the device must be considered.

Relatively few air-powered devices use air continuously. Pneumatic tools of all types operate intermittently and their net air consumption is considerably less than their maximum. The ratio of actual air consumption to the maximum continuous full load air consumption is known as "load factor."

Two items are involved in this term load factor. The first is the time factor or percentage of total time that the device actually uses air. Obviously, if a number of devices are operated from a compressor plant, and none of them operates all the time, it is reasonable to assume, and experience will bear this out, that the maximum air used in cubic feet per minute is much less than the total that would be required if they were all operating at the same instant at full load.

The second item in the term load factor will depend on what might be called the work factor, or the per cent of maximum possible work output per minute that is actually done by the device. For example, the air consumption of a grinder with full open throttle varies considerably, depending upon how hard the operator pushes it against the work. The work factor is, therefore, the ratio of air consumption at the actual conditions of operation to the air consumption when the tool is fully loaded.

Load factor is actually the product of time factor and work factor.

In one shop studied, the actual air consumed was only 15 per cent of the supposed full-time rated air requirements.

In a large installation the actual load was only 7.6 per cent of the load that might be expected, based on the total tools in operation, plus stock and reserves. If the air supply had been figured correctly on the tools actually in use, the air required would be 15 per cent of the requirements for the tools in use.

In determining load factor, care should be taken to eliminate the tools on hand in the store room or not in use.

It would be wise to discuss these points in detail with the tool manufacturer before finally deciding on the actual air consumption needed.

The above remarks apply to the more steadily operated air tools and appliances. A study of the uses of air power that cause heavy but usually short-time demands will develop added capacity required for these operations. The possibility of storing air in large receivers should be considered although this can be helpful only to provide for peak demands of very short duration.

Some comment should be made on the practice of adding a percentage to calculated compressor capacity to provide for piping leakage. This has been due largely to the fact that compressed air is so harmless that it is not considered vitally necessary for an air system to be tight. Electrical lines must be carefully insulated—leaks cannot be tolerated. Steam lines are kept tight because of danger and also because steam leaks are objectionable. Refrigerating systems must be tight, both because leakage is expensive and the gas is frequently obnoxious.

There is no more justification for allowing compressed air wastage than there is for buying a compressor with capacity controls, letting it operate continuously at full capacity and discharging the surplus through relief valves to the atmosphere.

Previously, it has been customary to add an arbitrary item of about 10 per cent for leakage. Compare this to an acceptable limit in the fuel gas distribution field of less than 1 cu ft per min per mile of 3-in. line. Air lines can be made just as tight as other piping systems and can be kept tight. It pays to do so.

Before determining the final compressor capacity, consider carefully that once compressed air is available, its versatility will of itself lead to a magnitude of profitable uses and applications not originally anticipated. Although mechanically it is no problem to increase the size of a compressed air plant since any number of units can discharge into the same system, it is prudent to provide some excess capacity for growth when the plant size is originally considered, including piping system. What this excess capacity for future growth should be will depend largely on individual conditions and total known requirements.

It is less difficult to arrive at the proper capacity needed for a plant extension than for a new installation. Local experience, compressor load factors, tool load factors, etc., either known or readily determined, provide a sound basis for decision.

The most frequent indication that more compressor capacity may be needed for an "overloaded" plant is *low air pressure*, which reduces shop production alarmingly. This is discussed in Part 2 of this article.

Based on a careful log of the pressures throughout the production areas, present compressor operating load fac-

*Based on material contained in the new "Compressed Air Handbook" published by Compressed Air and Gas Institute.

Cameron Flow Wing

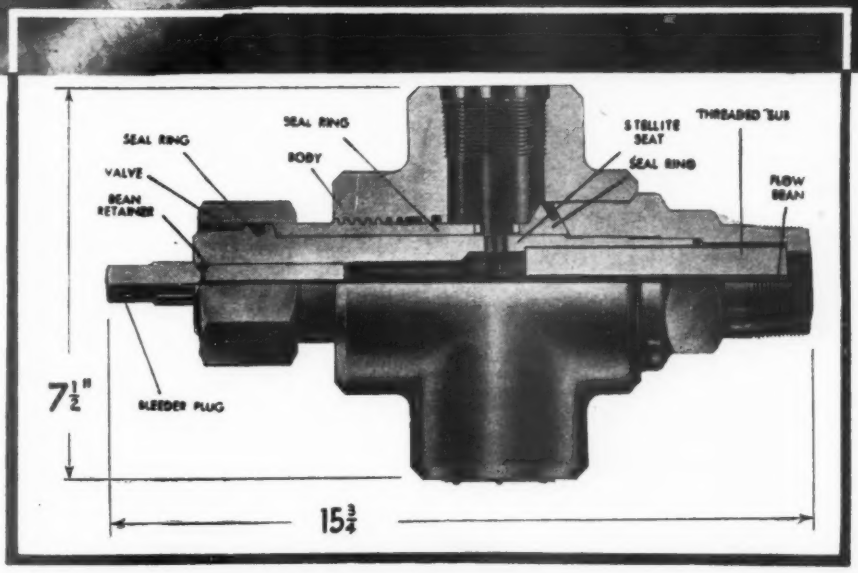
Here is the latest development in Flow Wings by the manufacturer who pioneered the unitized Xmas tree wing: the Cameron Type "F" Forged Steel Flow Wing.

The cross-section view at right clearly reveals the simplicity, the soundly engineered design, and the compactness of this new unit which combines an efficient wing valve with an interchangeable positive or adjustable choke.

To change beans you simply fit the all-purpose wrench to the valve stem and close the valve, back out the bean retainer with the same wrench, (the bean is retrieved with the retainer), replace the bean and reverse these operations. As a safety measure, the bean retainer cannot be removed until the valve is closed.

An adjustable stem and seat interchanges with the positive bean and retainer illustrated in the cross-section view. This conversion, or any maintenance required, can be done without removing the unit from the well.

Complete details will gladly be sent to interested operators on request.



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tors and peaks in demand (periods of unusually low air pressure), it is possible to determine with reasonable accuracy the additional compressor capacity required to maintain full air pressure at the working positions and thus increase tool effectiveness and production to the maximum. (Note: In all calculations compressed air measurements should be in terms of cubic feet per minute of *actual free air.*)

● **Number of compressor units.** The number of units into which total capacity should be divided is important. Air compressors are sturdy machines but, like all mechanical equipment, they require maintenance and must occasionally be taken out of service. Compressed air supply during maintenance periods is provided for differently in almost every plant. If the supply of compressed air is vital to continued production, the answer is usually determined by a comparison of the cost of standby capacity with the value of the production loss.

Many plants require a relatively small volume of air continuously, even when the plant is not in production. A small unit of proper size to take care of such requirements over week-ends, holidays, etc., is often desirable and efficient. Examples of such requirements are dry pipe sprinkler systems, oil burners on furnaces that must be kept hot over night or week end; air supply for tools used by plant maintenance crews over week ends, etc.

● **Location of compressor units.** The location of a compressed air plant with relation to the points of air use should be given some study. A central plant housing all the compressors involved has advantages in unified operation and care, better supervision, and probably less labor cost. In a central plant, it is probable that no more compressors will be kept operating than are necessary to maintain pressure. The load factor and operating efficiency of each unit will, therefore, tend to be relatively high.

It is possible, however, that a central plant cannot be so located that satisfactory distribution of air and maintenance of pressures may be obtained without excessive piping costs. In such a case, it may be better to divide the compressor plant into two or more installations at or near specific load centers, interconnecting the plant piping so that air may be distributed either way to meet peak load requirements. Of course, the plant should be placed as close as possible to the larger load centers. This reduces piping costs and results in higher pressure at the tools with closer control of the pressure.

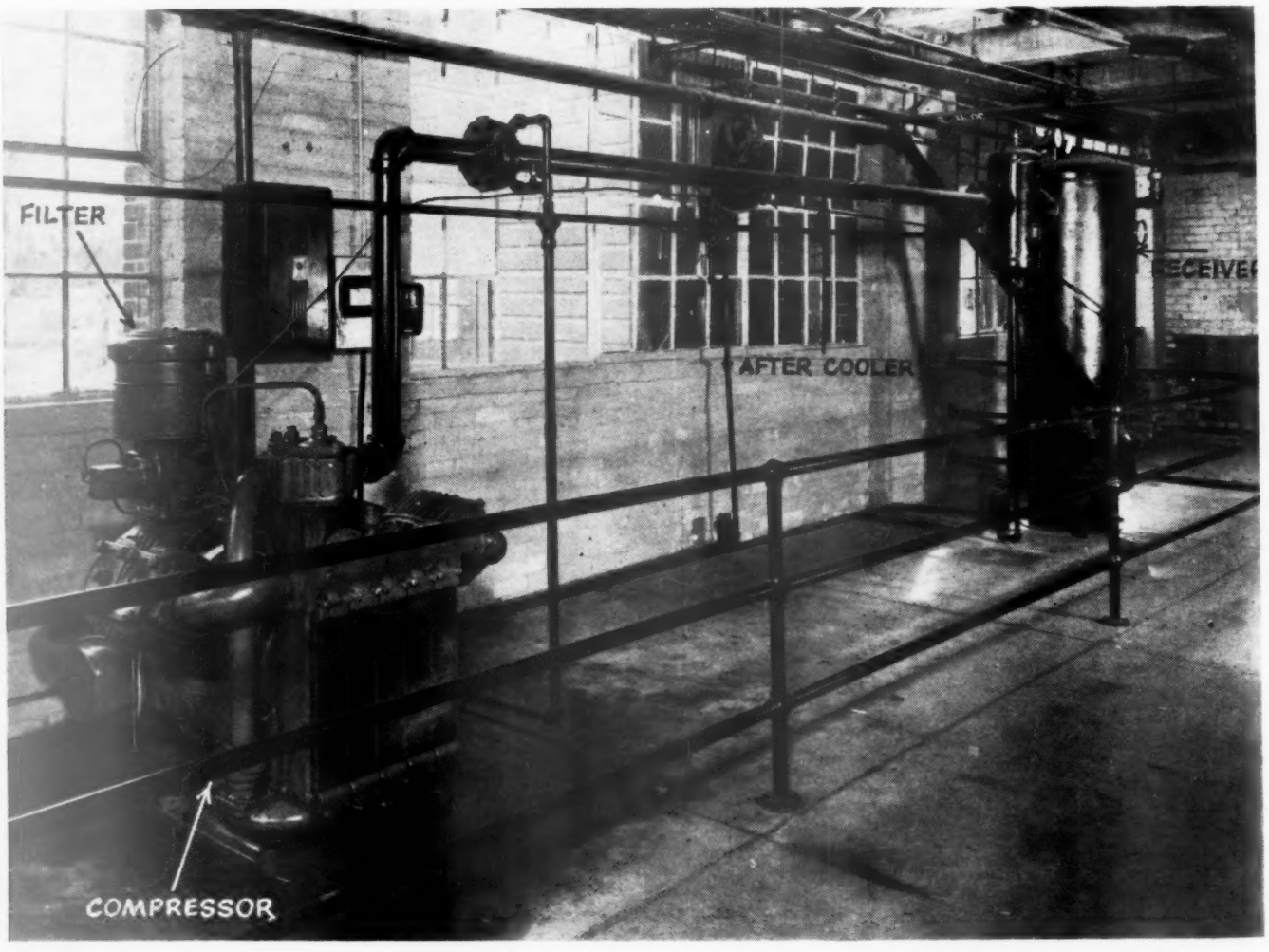
Where two or more compressors are installed in various parts of the plant, the equipment should not be placed in some obscure corner with no one to look after it. Such an installation will surely be neglected with costly consequences.

● **Regulation of compressed air plants.** As the demand for compressed air usually varies widely from time to time, some form of capacity control is required. Two general methods are available. The first, known as speed and pressure regulation, varies the speed of the compressor according to the demand for air such as is usually done in a steam-driven compressor. The second, known as constant speed regulation, operates the compressor at a constant speed and varies the capacity by any one of several types of unloading systems as is usually done in a motor-driven compressor.

For general industrial use, control of pressure closer than a 5 per cent range between full load and no load is unnecessary and should be avoided. Much closer regulation of the pressure can be provided where special conditions require it.

Wherever possible, pressure regulators should be so selected and adjusted that large units will act as base load units and unload only after smaller units have been shut down. Of course, where the requirements have diminished to

FIG. 1. Small two-stage air-cooled compressor complete with driver, filter, pipe-line type aftercooler and receiver.



where one of the smaller units would be sufficient, the large unit should be shut down. In this way, the overall economy will be improved.

● **Compressed air distribution system.** Any drop in pressure between the compressor and the point of use of the compressed air is irrecoverable loss. The distribution system is, therefore, one of the most important elements of the compressed air plant. In planning it, the following general rules should be observed:

1. Pipe sizes should be large enough so that the pressure drop between the receiver and the point of use will not exceed 10 per cent of the initial pressure. Provision should be made not only for present air capacity but also for reasonable future growth.
2. Where possible, use a loop system around the plant and within each shop and building. This gives a two-way distribution to the point where the air demand is greatest.
3. Long distribution lines should have liberal size receivers situated near the far ends or at the points of occasional heavy use. Many peak demands for compressed air are instantaneous or relatively very short and storage capacity near such points avoids excessive drop.
4. Provide frequent outlets on each header or main for attaching hose for air-operated equipment, always putting the outlet at the top of the pipe line to prevent carryover of condensed moisture to the tool. Frequent outlets result in shorter hose length and, therefore, less pressure drop through the hose.
5. Arrange all piping so that it slopes toward a drop leg or moisture trap in order that condensed moisture may be removed from the piping system and prevent it from being carried over into the air tools or compressed air-operated devices where it is harmful.

In planning the distribution system, it should be remembered that over-size piping costs little more than smaller size because most of the initial expense is for labor.

● **Type of compressor.** Following the five analyses, and through consideration of the data obtained, the selection of the particular type of compressor—that is, reciprocating, rotary, or centrifugal—should be based on consultation with various manufacturers whose engineers are best qualified to make such recommendations.

Before finally determining the precise type of compressor to be installed, consideration should also be given to the various types of power used to drive compressors—electricity, steam, oil, gas, or gasoline. The type of drive deserves careful study from the standpoint of first cost, operating cost, reliability of power or fuel supply, and maintenance. Anticipated plant load factor will also occasionally have a bearing on the selection.

The above discussion has been in the general nature of an outline. Manufacturers of compressed air equipment maintain trained staffs qualified to advise on specific problems in the generation and distribution of compressed air power.

PART 2

Low air pressure. Its causes, effects, and remedies.

Low air pressure is an abuse of the compressed air system—it is a costly and wasteful practice that should not be tolerated. Ignorance of the effects of low air pressure contributes more than any other single factor to a lack of appreciation of the effectiveness of compressed air power.

By low air pressure is meant inadequate pressure at the tool or the device that is air-operated. It is at this point that the air is used as power. Only the pressure and volume of air available at the point of use can be effective in doing work. Most pneumatic tools, for example, are designed to operate at 90 psig maximum at the tool. This means pressure at the point where the air enters the tool while the tool is operating. If the pressure is below the range of 85 to 90 psig, then it should be considered too low, for it reduces the ability of the tool to do the maximum work for which it was designed.

● **Causes of low air pressure.** The causes of low air pressure are easily classified:

1. Insufficient compressor capacity.
2. Inadequate piping.
3. Leakage.

When it is discovered that pressure is too low, the first inclination is to install more compressor capacity. That is not necessarily the correct answer. It should first be determined whether the compressors are at full load when the air pressure is low. If they are, then more compressor capacity may be required but, even then, consideration must first be given to two other common causes of low air pressure.

The second cause is inadequate piping. A measure of the adequacy of piping is the pressure loss between the air receiver, where the compressor endeavors to maintain a constant pressure, and the point of use. This should not exceed 10 per cent in a well designed system. The absolute maximum drop for the worst point in the system should not exceed 15 per cent. If the pressure drop is greater than 10 per cent average, 15 per cent maximum, throughout the entire distribution system (including hose), then attention should be given to correction of this fault before considering increased compressor capacity.

A third cause of low air pressure is leakage or loss of air without doing work. It has been pointed out that permitting excessive leakage is the same as exhausting the output of a compressor directly to atmosphere.

Obviously, if leakage is eliminated, the compressed air formerly wasted will be available for useful work. The expense of making lines tight will undoubtedly be less than the installed cost of a new compressor, whereas the daily power saving may be considerable.

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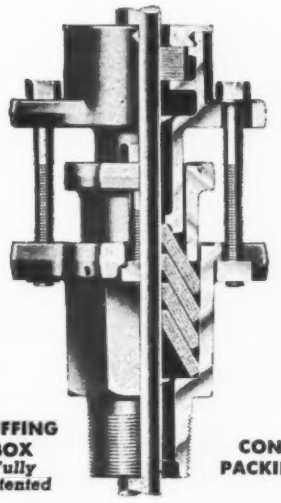

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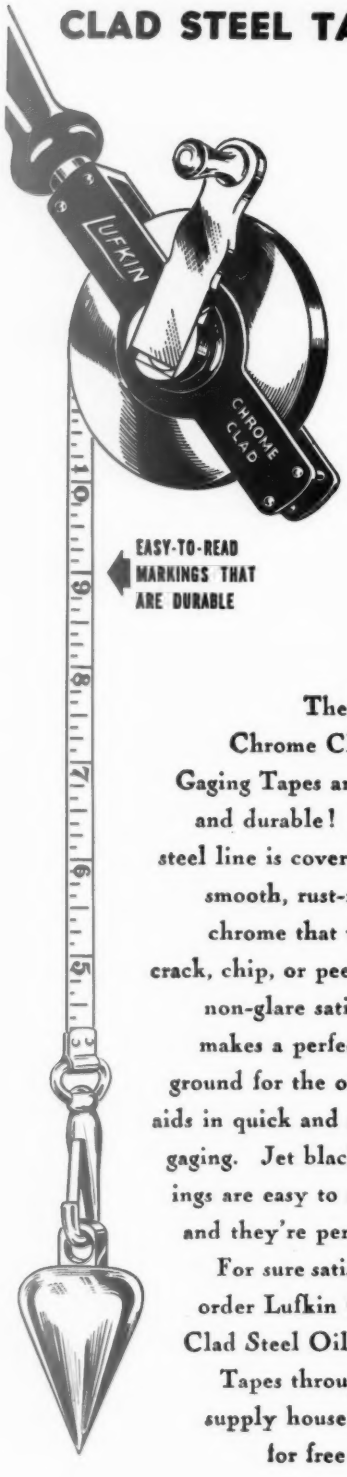

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more than one cubic foot per mile of 3-in. line as excessive.

Elimination of leakage is certainly a sensible step toward maintaining air pressure and conserving power.

● **Effects of low air pressure.** There are very few uses of compressed air not vitally influenced by low air pressure. All portable pneumatic tools, rock drills, concrete breakers, hoists, scrapers, loaders, all pneumatic transfer and conveyor systems, paint sprays, oil burners, sandblasts, air lift pumps, etc., operate less effectively when the proper air pressure is not maintained.

The positive result of increasing air pressure to the proper value is:

1. Increased production.
2. Reduced cost per unit produced.

The economic advantages of increased air pressure (or conversely, the losses due to low pressure), can be nicely illustrated by considering portable pneumatic tools. For example, an average increase of 37 per cent in production can be obtained for about 30 per cent increase in air consumption by increasing the air pressure at the tools from 70 to 90 psig.

Consider an installation of 20 tools operating from an $8500 compressor plant, first at 70 psig and then at 90 psig.

With power at 1 cent per kwhr, fixed charges at 15 per cent of installed cost, plus labor and supplies, air at 100 psig pressure costs 5 cents per 1000 cu ft.

The following tabulation brings out pertinent data:

Operating air pressure at compressor (psig)	100	100
Operating air pressure at tools (psig)	70	90
Tool load factor (per cent)	33	33
CFM required per tool at maximum load	50	68
Number of men and tools	20	20
Total CFM used	333	453
Total cu. ft used per 8-hr day	160,000	217,600
Cost of air per 1000 cu ft	$0.05	$0.05
Cost of air per day	$8.00	$10.88
Increased air cost		$2.88
Labor rate per 8-hr day (incl. burden)	$16.00	$16.00
Total labor cost per day	$320.00	$320.00
Total cost per day	$328.00	$330.88
Ratio of air cost to total cost (per cent)	2.4	3.3

Assuming that only one-third of the 37 per cent increase in tool productivity can be translated into labor productivity, it is evident that 12 per cent more actual work will be accomplished with 90 psig air pressure than with 70 psig air pressure. The work previously done for $328 can now be done in less time and will reduce the cost to $330.88 divided by 1.12, or $294.71. Thus, even though air costs are increased, there is a net saving of $33.29 per day, or about $8500 per year (equal to the first cost of the compressor plant).

Analyzing this another way, when the pressure is increased to 90 psig, the tools require 120 cu ft per min more air. A compressor with motor and auxiliary equipment to supply about this amount of air would cost $2200. The saving of $33.29 per day would pay for this new unit in 68 working days, less than three months.

When the question arises of purchasing additional compressor capacity as opposed to making other arrangements for the operations involved in a shop, it should be remembered that adding to compressor plant capacity frequently affords protection for many vital shop operations other than the operation of pneumatic tools. Among these are sandblasting, paint spraying, hoisting, agitation of liquids, air jet vacuum equipment for cleaning foundry sand, operating controls in power plants, air chucks in a machine shop, safety devices on punch presses, air jets for ejecting parts from presses, etc.

● **Remedies for low air pressure.** The remedies for low air pressure are just as definite as the causes and effects.

Faulty air power conditions are usually due to poor planning or to increased air uses without corresponding system expansion. Plant-wide analysis should determine the full extent of low air pressure and the present air flow requirements. Future growth must also be considered.

Pressure loss varies roughly as the square of the velocity of air flowing through the pipe. For example, a 3-in. line, 1000 ft long, will handle 500 cu ft per min with a 2.5 psig pressure loss, while a 4-in. line will pass about 1000 cu ft per min with the same drop. The installed cost of the 4-in. line will, however, be very little more than that of the 3-in. line, for most of the cost is labor.

Methods of increasing pipe line capacity to decrease pressure loss and improve conditions at the period of use vary with different installations. One may call for a line paralleling the original, with frequent interconnections; another may require installation of a loop system with some outlets taken off the new line to relieve the old; still another may need a complete new system.

Branch lines and manifolds for attachment of tools, etc., should be planned "oversize".

Not the least of the problems of correct system layout is the selection of proper hose for final transmission of compressed air to the tool. Losses of 15 to 25 per cent in air pressure are frequent in the hose alone. *Don't* use a hose longer than is necessary to make the tool available to the work and to give proper freedom of movement to the operator.

Every cubic foot of leakage eliminated is pure gain. Such losses in many systems will reach 10 to 20 per cent of the total air compressed. An air leakage test should be run on the complete plant and every section of hose should be inspected. Although leaks are usually small, they may be numerous, having a high total effect. A single 1/16-in. hole will waste 182,000 cu ft per month, costing $9.10.

The most likely locations of small leaks is around valve stems, in hose connections, unions, drains, homemade blow guns, and lines leading to inoperative tools.

Elimination of leakage involves making the system tight, then *keeping it tight*. Regular inspection is mandatory.

Only after it has been determined that the distribution system is adequate and that leakage has been eliminated, should increase in compressor capacity be considered. ★ ★ ★

Method of least squares applied to bottom hole pressure gage calibration

By MURRAY F. HAWKINS, JR.,* Louisiana State University

EXCLUSIVE

In the handling of data it is frequently desirable to represent the values in the form of an equation or formula in preference to a graph or plot. This is an advantage where the derivative of a curve, i.e., the value of its slope at every point, is desired rather than, or in addition to, the original curve. Here the labor and the errors involved in graphically determining the slope at numerous points are eliminated by simply differentiating the equation that represents the data according to the rules of calculus. Similar treatment may be applied to other derived results such as the cumulative area beneath a curve or the combination of two sets of interrelated values to obtain a third set. Many applications of this method are found in the problems of reservoir engineering.

Another instance where it is advantageous to represent data by an equation rather than a graph is in the handling of bottom hole pressure gage calibrations. Here the accuracy approached is of the order of ¼ per cent of the full scale reading of the instrument; and attainment of this accuracy can be materially aided, as is shown later, through the elimination of several errors attending plotting the data, namely, (1) errors involved in plotting the calibration values on coordinate paper, (2) errors involved in estimating and drawing the best straight line through the plotted points, (3) errors involved in subsequently taking values from the graph, and (4) errors inherent in the method such as non-linearity of straight-edges and non-uniformities of coordinate paper.

Handling the data mathematically, let us call it, not only eliminates certain errors mentioned, errors that are shown to be of significant magnitude, but also provides a method of greater convenience to the engineer who must handle a large number of bottom hole pressure measurements, as in fields where there are many wells on which shut-in and flowing bottom hole pressure tests are made monthly or bi-monthly.

The idea then is to calculate the equation of the straight line, or slight curve if such it should be, that best fits the calibration data; that is, to find the equation of the straight line (or curve) of Fig. 1 that on the average comes closest to all points. Among the mathematical tools that have been developed to determine the best straight line, the Method of Least Squares is one of the more simple. It is a statistical method that weighs the points properly, giving more weight to larger values that are of greater influence in correctly determining the slope and intercept of the line.

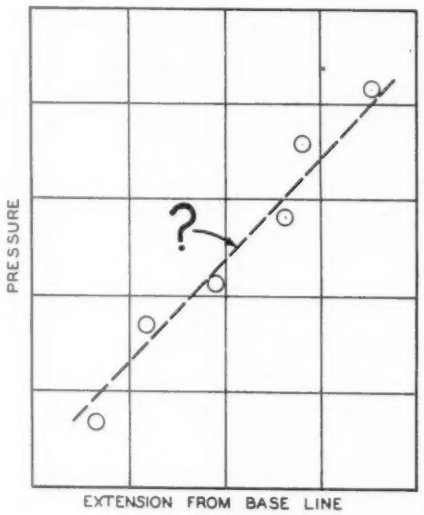

FIG. 1

The Method of Least Squares may be stated mathematically by defining it as a method for determining the equation of the best line or curve that represents or can be drawn through two or more pairs of data, provided the data can be represented by a polynomial expression, i.e.:

$$Y = a + bx + cx^2 + dx^3, \text{ etc. .} \quad (1)$$

Actually what the method does is to determine the values of the constants a, b, c, d, etc.

In passing it is pointed out that over a fairly extended region a polynomial can quite closely represent logarithmic, trigonometric, and other such functions, although there are more precise methods for handling these functions.[1] It is also of interest to point out that it is the inherent nature of most physical instruments that their calibration curves are expressible in terms of a polynomial. Thus in precision work with thermometers it is found that the length of the mercury column may be expressed by:

$$L = L_o\ (1 + aT + bT^2 + cT^3,$$

$$\text{etc.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where L_o is the length at some reference temperature and L is the length at any temperature T; a, b, c, etc., are constants.

In the rest of this article the Method of Least Squares will be demonstrated by an application to the handling of the calibration data of a bottom hole pressure gage given in Table 1.

TABLE 1. Calibration data for a BHP gage at 203 F.

Pressure by DWT, psig (y-values)	Extension from the base line in inches (x-values)
800	0.333
1600	0.669
2400	1.002
3200	1.338
4000	1.671
4600	1.925

Assuming the calibration curve to be a straight line, substitute in the following equations:[2]

$$\Sigma Y_i = n\ b + m\Sigma X_i \quad . \quad . \quad . \quad . \quad (3)$$

and,

$$\Sigma X_i Y_i = b\Sigma X_i + m\ \Sigma X_i^2 \quad . \quad . \quad (4)$$

Where:

ΣY_i = the sum of the pressures at each of the six calibration points,

ΣX_i = the sum of the extensions at the points,

$\Sigma X_i Y_i$ = the sum of the products of pressure and extension at each point,

ΣX_i^2 = the sum of the squares of the deflections at the points,

n = the number of points (here six),

m = the slope of the best straight line in psi per in.,

b = the y or pressure intercept of the best straight line in psi.

Substituting the values:

$$\Sigma Y_i = 800 + 1600 + 2400 + 3200 + 4000 + 4600 = 16{,}600,$$

$$\Sigma X_i = 0.333 + 0.669 + 1.002 + 1.338 + 1.671 + 1.925 = 6.938,$$

$$\Sigma X_i Y_i = (800)(0.333) + (1600)(0.669) + (2400)(1.002) + (3200)(1.338) + (4000)(1.671) + (4600)(1.925) = 23{,}562,$$

$$\Sigma X_i^2 = (0.333)^2 + (0.669)^2 + (1.002)^2 + (1.338)^2 + (1.671)^2 + (1.925)^2 = 9.8506.$$

Substituting in equations (3) and (4):

$$16{,}600 = 6\ b + 6.938\ m$$

$$23{,}562 = 6.938\ b + 9.8506\ m$$

Solving these equations by multiplying the first equation by 6.938/6 or 1.15633:

*Assistant professor of petroleum engineering.

$19{,}195 = 6.938\ b + 8.0226\ m$
$23{,}562 = 6.938\ b + 9.8506\ m$

Subtracting these two equations to eliminate b:

$4{,}367 = 1.8280\ m$ or $m = 2388.9$ psi. per in.

To find the value of b, substitute this value of m in the first equation:

$16{,}600 = 6\ b + (6.938)\ (2388.9)$

$b = 4.3$ psi.

Then the final equation representing the calibration of the instrument is:

$y = 2388.9\ x + 4.3$ . . . . (5)

where y is the pressure in psig corresponding to a stylus deflection x. For example, a deflection of 1.374 in. would indicate a pressure of:

$y = (2388.9)\ (1.374) + 4.3$

$y = 3282.6$ psig.

This is the pressure at 203 F and temperature correction is applied by one of several methods, at the choice of the individual. It is pointed out that the use of a calculator or five place logarithm tables is indicated, particularly in determining the constants of the equation.

It is of interest to measure the "fit" of this calculated equation to the data. Table 2 provides this information wherein the applied pressure is compared with the pressure calculated by substituting the measured deflection in the equation (5).

The magnitude of the average deviation is of value in that it is a reliable indication of the quality of the calibration job and/or the physical condition of the pressure gage. Had there been reason to suppose a slight curve would have fitted the data better than a straight line, other coefficients of equation (1) could have been determined as shown in reference (2). Conversely, if the coefficients of x^2 or higher powers of x

TABLE 2.

Deflection in inches	Calculated pressure (Equation 5)	Applied pressure, psig	Absolute deviation, psig
0.333	799.8	800.0	0.2
0.669	1595.3	1600.0	4.7
1.002	2397.0	2400.0	3.0
1.338	3200.6	3200.0	0.6
1.671	3996.1	4000.0	3.9
1.925	4602.9	4600.0	2.9
		ΣDeviations	15.3

$$\text{Average deviation} = \frac{15.3}{6} = 2.6 \text{ psig}$$

are found to be of significant magnitude, then the fit of a curved line is indicated in preference to a straight line. With so few points as the six used here, however, chance may indicate a curve where in fact none exists. That is to say that many more points are required to indicate reliably the existence of a slight curve, whereas six is considered sufficient to determine accurately the two constants of a straight line.

To show that the method herein described does eliminate some error involved in using a graph, numerous random stylus extensions were taken and the corresponding pressures read from a chart based on the same calibration data of Table 1. These pressure were then compared with those calculated by substituting the assumed stylus extensions in equation (5). The chart from which the readings were taken was prepared by a commercial laboratory that provides BHP gage calibration service, and measured 14 in. by 24 in. on coordinate paper that had smallest pressure divisions of 10 psi and smallest extension divisions of 0.01 in. In these tests of over a hundred trials an average deviation of ± 4 psi was found from the mathematical or true value.

In conclusion, it is emphasized that a feature probably as important as that of reducing error by using this method is that of convenience.

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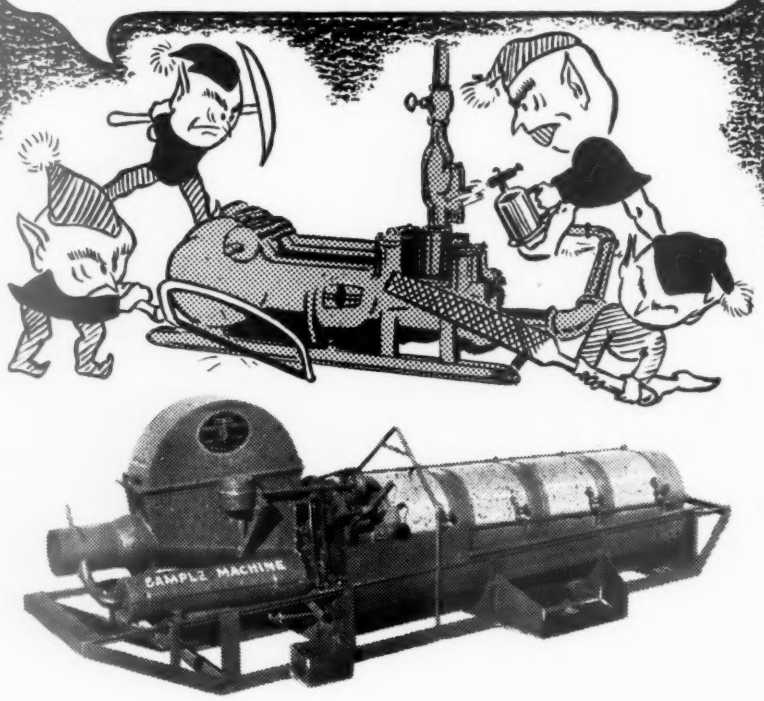

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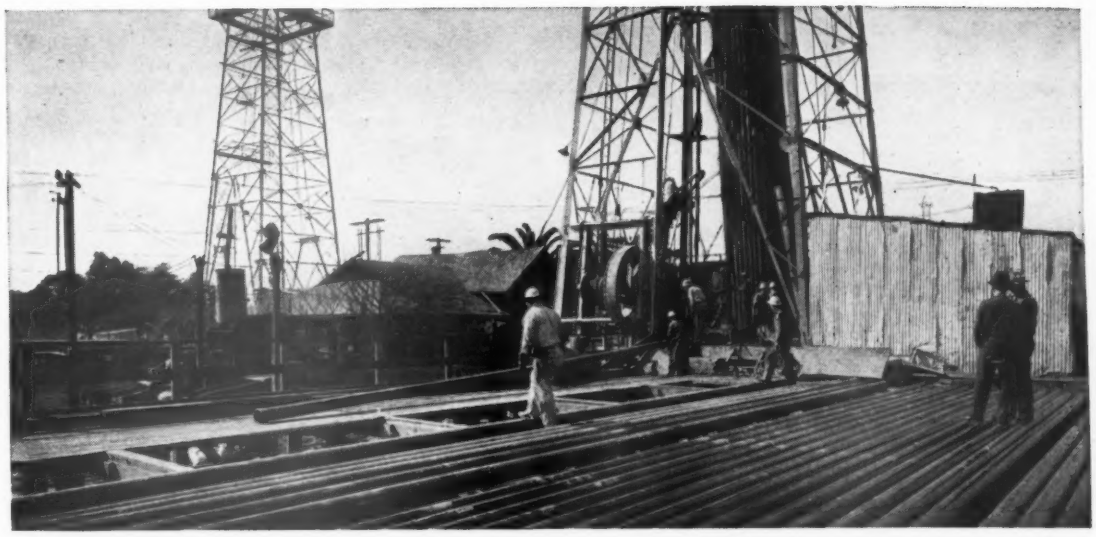

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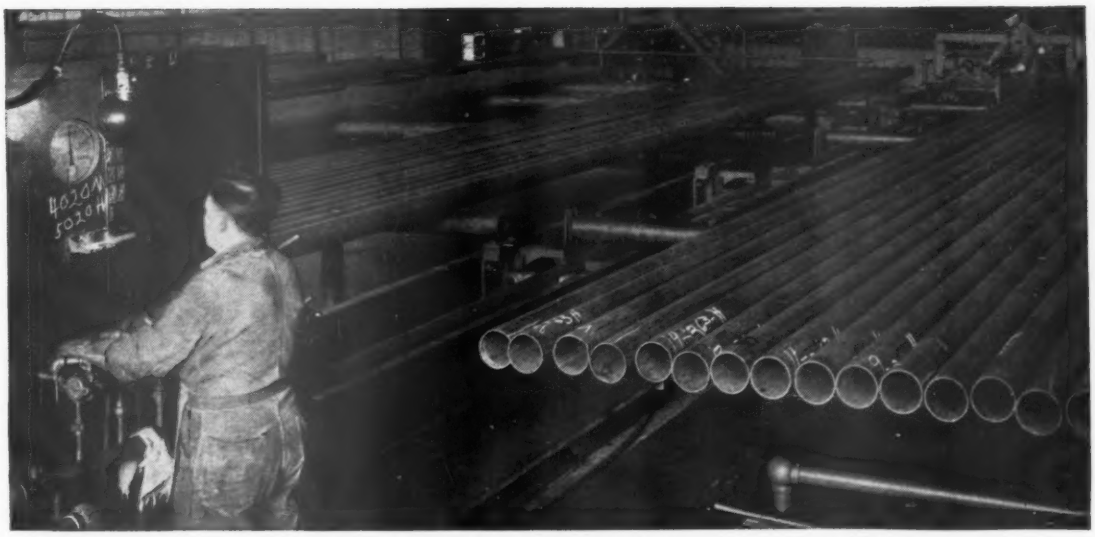

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Houston Natural Gas Corporation

EXCLUSIVE

IN 1880, Henry W. Grady in describing a southern funeral wrote, "The grave was dug through solid marble, but the marble headstone came from Vermont. It was in a pine wilderness, but the pine coffin came from Cincinnati. An iron mountain overshadowed it, but the coffin nails and screws came from Pittsburgh. With hardwoods and metal plentiful, the corpse was hauled on a wagon that came from South Bend, Indiana. A hickory grove grew nearby, but the pick and shovel came from New York. The cotton shirt on the dead man came from Cincinnati, the suit from Chicago, the shoes from Boston, the white gloves from New York, and round the poor neck that had borne all its living days the bondage of lost opportunity, was twisted a cheap necktie from Philadelphia. All that the South contributed to the funeral of one of its sons, was the corpse and the hole in the ground." This story was written 67 years ago, but despite the progress in agriculture and industry during that period, the South still imports 80 per cent of its daily necessities from outside its great, rich area; although its natural resources are so tremendous that it can supply almost all its needs.

At present, Southern dairies are forced to buy part of their milk supply from Indiana and Wisconsin, while thousands of acres of fertile land adaptable to improved pasturage lie nearby; cotton farmers buy textiles made in the East from raw materials raised on their own land, and the rancher pays a fancy price to a Northern cobbler for boots made from hides removed from the cattle he shipped to Iowa to be fattened on corn. Such a system is fundamentally wrong and althought no attempt will be made in this article to solve a problem that seems to have baffled some of the best economists of our times, a few observations may arouse enough interest to prompt further research.

It is well known that almost 80 per cent of the natural gas supply in this country has been found in the South, and as fuel is a very important medium in the development of either an agricultural or industrial economy, it goes without saying that all the gas companies should be eager to foster any feasible program of natural resource development.

A natural gas pipe line should be considered to be an important life-line of progress just as much as a railroad or a modern highway, and recent natural gas pipe line extensions and proposals have, or will, make natural gas available in large quantities all through the South, and like railroad and highway will reach the important places. As a result, the natural gas industry has a tremendous challenge to stimulate and help in the development and processing of Southern resources.

The South, as has been said before, is rich in raw materials and there are many industries in the territory that are using them. These industries have been attracted by the abundance of cheap fuel now available, but it is essential for the natural gas companies to view its potentialities from a long range standpoint.

At this particular time, it seems appropriate to look into the problems of agriculture, because shortage of food and feed make conservation of nutrients imperative. Two methods by which farm products can be saved from early deterioration are available to many farm producers, namely dehydration and quick-freezing. Both of these have a distinct application, and the gas industry is involved either by direct gas application in dehydration, or indirectly by power generation in quick-freezing.

If the gas industry elects to promote these conservation measures, it is necessary for some member of each company to become familiar with the processes.

In dehydration operations applied to cattle feed, a certain amount of free moisture is removed in order to make the product stable against loss or deterioration of its protein or carotene contents.

Feeds such as alfalfa, cotton seed, peanut and linseed meal, and many forage grasses, as well as the cereal grasses, which include wheat, rye, barley, oats, and rice, are rich in protein and carotene, and when dehydrated bring a higher price. Corn, milo chop, and sweet potatoes are rich in carbohydrates and are well known stock feedstuffs. In fact, the sweet potato, which can be raised in abundance all through the South, if dehydrated, will yield a cattle feed production rivaling that of the north-central corn belt. By converting the present 34,000,000 acres of southern corn land to the growth of sweet potatoes—and this is said because it can be shown that an acre of sweet potatoes in the South is worth more than an acre of corn—a minimum of 1,155,000,000 bushels of carbohydrate feed could be produced annually. With a fuel consumption of approximately 10,000,000 Btu per ton, there is a tentative market of 288,000,000,000 cu ft of natural gas a year in the dehydration of this one crop for feed only. It must also be remembered that the sweet potato is an excellent source of starch and when processed for that end product offers still another fuel market.

The dehydration of alfalfa, other grasses, rice, grain, vegetables, and waste products offer another enormous fuel market of unpredictable volume.

Some conception of its size can be gleaned from the fact that the annual rice production in the United States exceeds 70,000,000 bushels and the alfalfa crop in 1947 amounted to about 637,000 tons in but four of the southern states.

Much of these two crops has been dehydrated, although not all with natural gas, so the gas man has here not only a selling problem but a conversion one as well, for again natural gas is the ideal fuel.

Nor can the gas industry overlook the market possibilities in the processes that have been developed by the field of "Farm Chemurgy," which literally translated, means putting chemistry and related sciences to work in industry for the farmer, and indirectly, for society in general. Some of the transformations that take place between raw material and finished products seem to fit tales from Arabian Nights.

The most glaring examples are: The conversion of skim milk into casein, used in the manufacture of plastics and paints; the conversion of sheep skins into almost perfect synthetic furs; the use of wood pulp in making newsprint; and chemical research that shows that sawdust heaps and mounds of scrap lumber, heretofore discarded, will yield products ranging from ethyl alcohol to plastics, drugs, and flavors. Looking further, we find corn cobs and oats used in making furfural, a product very valuable in refining lubricating oils and producing nylon; glucoside—a fiber made from chicken feathers; zein, an alcohol-soluble protein, which is one of the most important products from corn, used in making plastics, in printer's ink, and as a base for adhesives; rutin, which comes from tobacco and buckwheat, and is used in the treatment of diseases affecting the blood; sarelon, a peanut protein fiber; houses made of straw; linoleum from wood flour; cattle feed from black-eyed pea hulls or other so-called waste products and on and on and on—.

The gas man knows that the very product that he sells is a raw material and that it can be processed for alcohol, gasoline, diesel oil, wax, and fatty acids, but he is primarily interested in selling his product as a fuel, especially if the sales can be made when the use of gas for heating purposes is at a minimum, or in other words, as an off peak load.

Dehydration procedures and the many new industrial plants that are bound to stem from chemurgical research offer such a market, and when so many types of fuel are available the gas industry can ill afford to pass it by. ★ ★ ★

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Pressure build-up cuts clean-out costs

By F. R. COZZENS, Equity Oil and Gas Company

EXCLUSIVE

One major requirement connected with reconditioning of stripper oil wells is to select those wells most likely to return a fair and early margin of profit over clean-out costs. This problem of selection is especially stubborn because oil-bearing sands differ widely in composition and structure, and no two wells will respond alike to the same method of treatment. An effective reconditioning of a supposedly worthless well often has provided the encouragement necessary to continue a recovery project during the critical early stages. On the other hand, the expense of cleaning and frequently working over certain key wells has been sufficient to throw an entire project off-balance and into the red.

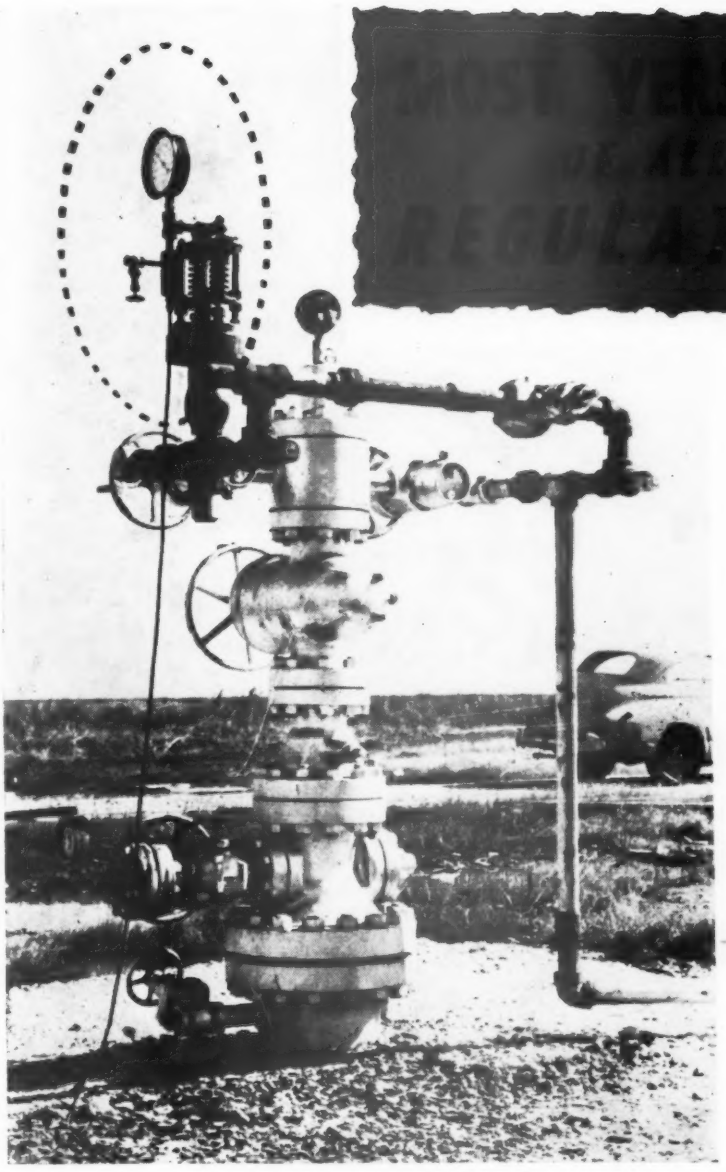
One rule-of-thumb formula, having at least a few adherents in every oil-producing district, is that wells having a natural oil production of one barrel or less per day are not worth cleaning out. Their records, verified by actual field tests in many localities, show that it costs from $300 to $1000 to recondition the average stripper well; fully one-half the amount being spent for labor and materials (paraffin solvents, acid, explosives, etc.). Assuming that results are favorable, it is pointed out that three to ten years' continuous production would be necessary for low bracket wells before the operator could realize a profit over and above his investment in a clean-out job. Without doubt, such has been the case among a few operators in every field, but the selection theory is not always right and if strictly adhered to 30 to 45 per cent of all stripper wells would soon be abandoned or go uncleaned and give continuous trouble and expense. Cleanout costs are too high at present, being three to five times higher than they were in the early days.

Rising costs of material and labor have had much to do with increased expenses, but another factor, often overlooked, is that natural gas pressure in most stripper fields is so low that it is insufficient to force the oil into the wells. Without sufficient force, oil that accumulates behind the sand face will not flow into a well. Consequently, all the usual clean-out methods are confined entirely within the shot-hole, and quite often, after the sand face has been thoroughly treated and cleaned off, there is still sufficient sludge and paraffin immediately behind it to reduce production. This fact is frequently exemplified on successful air- or gas-pressured projects where original sand conditions have been duplicated so far as possible. On such projects, old wells respond more favorably to clean-out methods with less effort and expense involved. Lower producing wells can often be cleaned at a profit because the operator is aided by the artificial driving force already established in the sand.

No individual operator, of course, can afford or attempt to build up pressure in a dormant sand merely for the purpose of cleaning out his wells. He can, however, if either air or gas is to be used as a medium for the later recovery of oil, obtain the desired pressure benefits on clean-out jobs without interfering seriously with his production schedule. The plan, apparently, places the cart ahead of the horse, but eastern stripper field operators are finding by actual experience that it works. Methods of its application depend somewhat upon lay-out of the territory and type of pressuring equipment to be used, but generally the principle is put into action by injecting air or gas into a skeleton well pattern, leaving low producers to be cleaned out later after sufficient driving force has been built up in the sand.

The operator planning to use built-up pressure as a reconditioning aid, first locates an input well where it can be made to serve three to five producers. It is generally found advisable to drill the input wells because measurements are more likely to be accurate, and the driving force can be introduced to much better advantage. Unless the sand is very tight and restricted, a newly-drilled input well is not shot hard. The usual formula is to use one quart of straight nitroglycerine to each foot of pay sand, placing the shell at a point 2 ft below the top of the pay, and 2 ft above the bottom. The main purpose of such placement is to leave a natural shoulder for seating the casing, and to leave unfractured any "thief" formations immediately below the pay sand. After shot spoil and residue have been removed, a packer is set at the top of the pay and the well is tubed. The packer prevents the escape of pressure into upper stretches of hole and leaves the entire course of pay sand open for later zoning, if found necessary. Air or gas is injected into the input well as soon as completed. Other input wells, their locations previously having been charted, are drilled in succession and fitted out in the same manner until the entire project is arranged into skeleton patterns. Generally, these patterns are arranged so that later they will form 5-spots or 7-spots without too much distortion, although the principle is often carried out successfully with no regard to pattern. While input wells are being completed, all producing wells on the project are tested and the hopeless ones salvaged of casing and plugged. Besides sealing off the hole above the pay sand and filling the well to the surface, plugging also includes the closing of any pocket or extension that may exist below the shot hole. The shot holes in many old wells are partly filled with sand, sludge, etc., and for an effective plugging job, this residue should be pumped or bailed out. Careless plugging makes it practically impossible to build up a uniform pressure through an area of sand.

Producing wells showing any degree of promise after testing are closed in at the casinghead and inspected frequently. After a period of six to ten weeks, provided air or gas has been injected without interruption, fluctuations of fluid level will be noticed in certain wells, generally first in those nearest an input well. When such evidence of the pressure of injected aid or gas becomes clearly established, pumping equipment is removed, and a string of light clean-out tools is placed over the well. Shot-hole accumulations are first stirred up with the drill and bailed out until the bottom of the pay sand is free. For cleaning the sand face, chemicals such as carbide or lye generally are used. Various methods of applying chemical solvents are so widely known that it is needless to repeat them here. The operator must keep in mind, however, the fact that the purpose of chemicals is to generate sufficient heat within the shot hole to dissolve wax and paraffin. A bottom-hole temperature of not less than 100 to 130 F must be generated and maintained for eight to ten hours, and the solution, including residue, must be bailed out while still hot. Otherwise, a stubborn film will congeal over the sand face, leaving it in worse condition than before. Hydrochloric acid with inhibitors, although not a paraffin solvent, often is used successfully on clean-out jobs where the calcium content of the pay sand is 20 per cent or higher, and, in very tight or restricted sands, many operators prefer a "burn-off" with nitroglycerine. The usual quantity is 10 to 12 quarts, the shell being hung near the center of the shot hole. When explosives are used for cleaning purposes, care must be taken that the casing shoulder at or near the top of the sand is not broken. As measurements on many old wells are rather dubious, it is sometimes impossible to prevent a damaged shoulder, and when this occurs the operator replaces it with a cement bridge. The bridge provides the necessary shoulder and is constructed by filling the shot hole with sand to within a few inches below the top of the pay. The sand is wetted with water, and enough cement slurry poured in to fill



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the bore 6 to 10 in. above the point where the casing is to be seated. After the cement has hardened the bore is redrilled with a bit of the proper diameter and the sand bailed out. All types of clean-outs, whether with explosives or solvents, are followed by several wash-downs with salt water or an artificially made brine.

While shot-hole cleaning is in progress, there is little or no evidence of the driving force being generated through nearby input wells, but after the newly cleaned well has been left open for 10 to 12 hr and again bailed out the operator generally finds considerable residue, such as, cuttings, sludge, and strings of paraffin that were not in the shot hole at the time of previous bailings. This residue remained in the fractures and crevices of the sand face, beyond reach of the clean-out tools, and was forced into the well by air or gas pressure build-up within the sand. Because of this build-up, a free drainage system into the well has been provided, and the result is a more effective clean-out job with less effort and expense. Other wells on a project are likely to be found dormant, not because of paraffin accumulations, but because of a "sluggish" sand. Pressure build-up usually eliminates this condition without any shot-hole treatment. If certain wells on a project have been temporarily "killed" by fresh water (through casing leaks, etc.), the operator tries a revival experiment and is often successful. It is believed upon good authority that fresh water, after filling the shot hole, spreads out some distance into the sand in the form of a ring whose center is the well. This barrier must be destroyed before oil can reenter the well, and the job must be done before any force from the input wells has reached that area. The water-logged well is first pumped dry and the rods removed. An induction line direct from the compressor is connected with the tubing at the casinghead, and as much air or gas as possible is pressured into the well. Pressure accumulating within the shot hole causes the water ring to expand and grow thinner until it finally bursts. This result becomes evident when the well begins to take input air or gas at a favorable rate. After a favorable intake has been noticed for a few days, the pressure is released and the well allowed to blow-off. In most cases the operator is rewarded with a fair return of oil.

All clean-out and revival tactics are a part of reconditioning, and they are continued from well to well until all patterns on the project are filled in and completed. Cost records are kept, and if the sand in the project area is responding to induced pressure, it will usually be found that many low-producing wells can be reconditioned at a profit, mainly because the pressure aid is to be had at no extra expense. The wells not only clean out better, but they stay clean longer. Because of this fact, the pressure schedule operates to better advantage. As a result more oil is produced in less time, with substantial savings in the cost of recovery. ★ ★ ★

ANNUAL REFINING SECTION

Vapor recovery unit at El Dorado

By H. E. CHAMBERS*, and J. Y. HASLAM†, Skelly Oil Company

SKELLY OIL COMPANY decided some five years ago that the first step in a long-term modernization and expansion program for its El Dorado, Kansas, refinery would be the erection of complete modern vapor facilities. Due to the increased importance of propane recovery, both for the liquefied petroleum gas industry and for the production of high octane blending value polymer gasoline; and the advantages to be gained in motor fuel volatility by adequate fractionation of cracked gasoline stocks, the vapor recovery unit replacing the then-existing out-dated vapor recovery facilities was given preference over other steps in the modernization plan. The engineering design was for a propane recovery of 80 per cent with a purity of 98 per cent; and 99 per cent recovery of butanes. Observation during the last 12 months has indicated the operation of the vapor recovery unit has exceeded performance guarantees in all aspects. The charge to the vapor recovery unit consists mainly of the vapors and liquid (above 400 F end point) from the thermal cracking operations. The end products consist of fuel gas, propane, butane, polymer gasoline, and debutanized cracked gasoline.

EXCLUSIVE

Benefiting by the experience gained during erection of large size units during the war, the physical layout of the plant was aimed at providing maximum access to all equipment. The location of equipment, in connection with instrumentation, was also aimed at providing maximum efficiency of operating labor. Actual erection of the individual items of equipment largely followed the straight line flow, as indicated in the flow sheet shown. In the first row along the north side of the unit are the direct-fired vertical heaters. In the second row are the fractionators, caustic scrubbers, and propane driers. In the third row are the two pump houses, instrument room, blowdown water box, and caustic storage tank. In the fourth row are the reflux drums and in the fifth row are coil pit, water circulating pumps, and the cooling tower. The layout is very simple in construction and in operation.

With the exception of a few caustic lines, the blowdown lines, and the firewater lines, the piping is overhead. These lines were all prefrabricated, thus simplifying the assembly. There is positive liquid suction assured to all the pumps by all lines running horizontally or downward from the towers or drums to the pumps. The towers are elevated on skirts and the reflux drums are elevated in a manner to give liquid head above the pumps. On the two towers with direct-fired reboilers the bottoms products take off high enough above the bottom of the tower so that supply to the reboiler cannot be drained away in the bottoms product line.

Each pumping service has a spare pump. One pump is electric motor driven and the other is steam turbine driven. Four of the pumps have automatic starting valves on the steam turbines so that they automatically start when the electric power is cut off. These pumps are the two water circulating pumps and the two pumps circulating tower bottoms through the direct-fired reboilers.

There are three electric circuits, 2200 volts for the motors of 100 hp or more rating, 440 volts for all the motors of less than 100 hp rating, and 110 volts for lights and instruments.

A steam-driven air compressor and an air drier of 50 cfm capacity supply air for the controls and instruments.

At convenient points in the plant there are connections for steam, air, and water. The air is supplied from the plant air system and can be used for air-driven tools used in maintenance work. Steam hose are also conveniently placed. Adequate fire protection has been provided. All motors are the totally enclosed vapor-proof type and the entire electrical installation is explosion-proof.

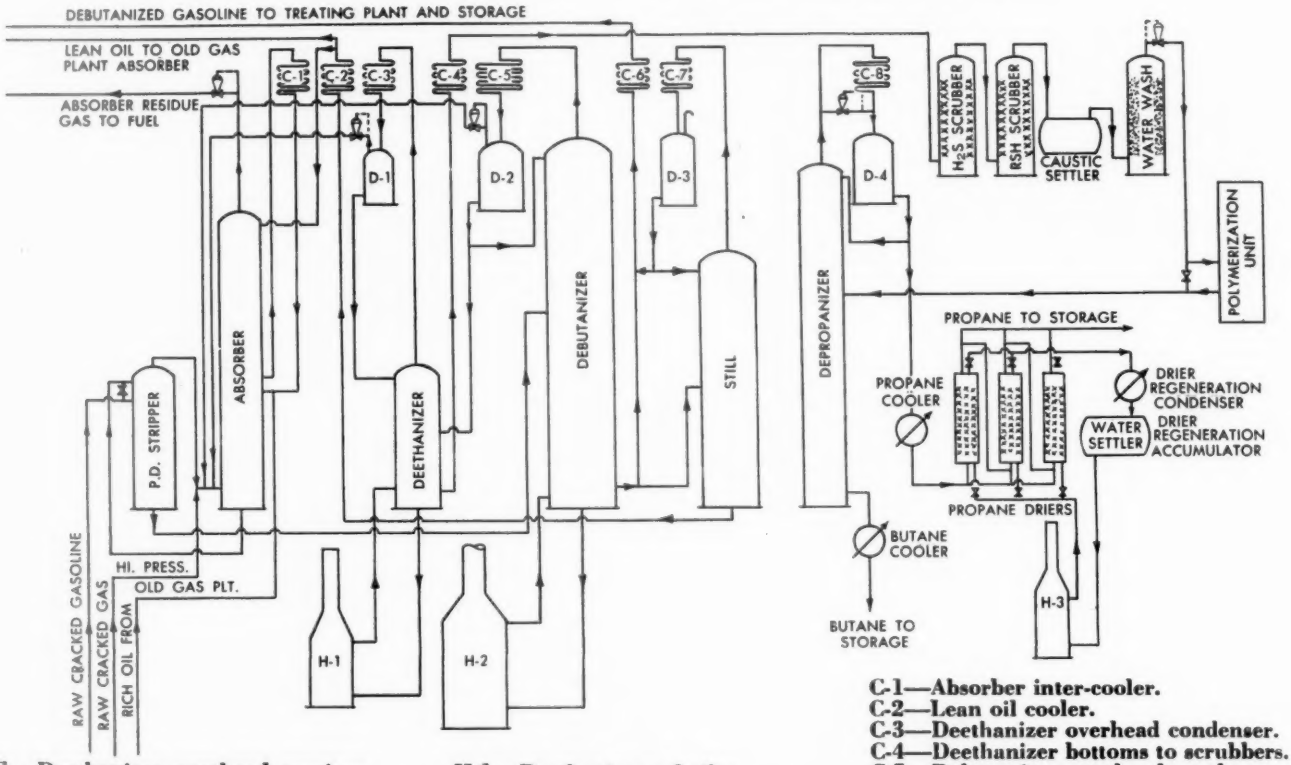
All piping is suspended to avoid strain on the pump connections, which might otherwise distort the pump body and cause excessive wear in the pump.

There are low cement retaining walls around smaller groupings of the heaters, fractionators, scrubbers, driers, and each pump room to provide a measure of safety against large-scale leakage. An adequate sewer system connects to each unit within this plant. A blowdown line with a check valve connects to a main blowdown line, which goes through a blowdown water box and then to a 10-ft diam by 40-ft tank. The vapors from all relief valves also go to this tank and a vapor line from this tank goes to a flare on top of a 12-in riser.

Before the plant was started up the operators and process engineers spent a period of two weeks in training, learning all the lines and equipment. This was an organized course of study under direction of the unit foreman and a process engineer. By the time the plant was started, each operator had studied the instructions for each piece of equipment

*Process engineer.
†Chief engineer.

FLOW SHEET OF VAPOR RECOVERY UNIT—SKELLY OIL COMPANY



D-1—Deethanizer overhead receiver.
D-2—Debutanizer overhead receiver.
D-3—Still overhead receiver.
D-4—Depropanizer overhead receiver.

H-1—Deethanizer reboiler.
H-2—Debutanizer reboiler.
H-3—Propane drier regeneration heater.

C-1—Absorber inter-cooler.
C-2—Lean oil cooler.
C-3—Deethanizer overhead condenser.
C-4—Deethanizer bottoms to scrubbers.
C-5—Debutanizer overhead condensers.
C-6—Debutanizer gasoline cooler.
C-7—Still overhead condenser.
C-8—Depropanizer overhead condenser.

and knew all the lines and valves and the flow throughout the plant.

As the equipment was completed by the construction crew the operating crew hydrostatically tested the units at one and one-half times the expected working pressure. Then dry gas pressure was put on the system to displace the water as it was drained. Ten pounds gas pressure was left on the system and water was drained from all low connections, gauge cocks, etc., for a period of 24 hr, or until no more water collected. The plant was then full of dry gas ready to be charged and started up. Very little trouble was encountered in starting other than leakage from the mechanical seal packing and the necessary time for adjusting the controls to balance out the operation. Mechanical seal packing is in operation on pumps handling gasoline, butane, propane, and on one pump handling a stream that is mostly a mixture of propane and ethane, at 480-psig suction pressure. This stream carries some mechanically entrained moisture and hydrogen sulphide, which makes the service doubly difficult. Some trouble was experienced with the packing in this particular service and a change is to be made to use an auxiliary oil stream that is non-corrosive in a double seal mechanical packing. We have one pumping service handling propane-butane mixture at 480-psig suction pressure in which the hydrogen sulphide content is comparatively low and there is no moisture content, and thus practically no corrosive condition, on which the mechanical seal has been quite successful. The temperature of this stream is 220 F.

From our initial starting experience using mechanical seals we believe seal packing should have been installed after the plant had operated a few weeks, or long enough for the scale and dirt to be washed out of the system, because some trouble was experienced with scoring of the seal faces from the dirt and grit in the sealing liquids.

The feed to this plant comes in three streams. One is the rich oil and condensate from the old gas plant. The compressors and absorber of the old gas plant are operating to handle the crude still vapors, tank vapors, and low pressure vapors from the cracking units. Absorption oil from the new plant is pumped over the old absorber, which operates at 60 psig and the rich oil, plus drip or condensate collected from the low pressure lines and scrubbers, is pumped together back to the new plant absorber, going in just below the middle of the new absorber. Enough absorption oil is put to the old plant absorber to get maximum C_3 recovery, and then it has a chance to do additional absorption at the higher pressure of the absorber at the new plant. The other two streams feeding this plant are one gas stream and one gasoline stream from the cracking stills.

The gasoline from the pipe stills, or pressure distillate, is heated by heat exchange and feeds into the PD stripper on the third tray from the top of the tower. The absorber rich oil feeds in on the top tray of this PD stripper. The vapors off the top go to the base of the absorber and the bottoms to the debutanizer. The top tower temperature is 120 F and the base temperature 210 F. The tower pressure is 155 psig. This pressure is maintained by the absorber pressure.

The gas from the cracking stills goes into the base of the absorber. The rich oil and condensate from the old gas plant go in on the thirteenth tray from the base. Lean oil goes in under the top tray in the absorber. Oil is taken from the fourteenth tray and cooled from 120 F to 100 F and pumped back in on the thirteenth tray.

Vapors vented from the debutanizer and the deethanizer enter the absorber along with the PD stripper overhead and the gas from the cracking stills. The lean oil flow over the top of the absorber is 112 gpm at 87 F. The gas temperature in is 110 F and the rich oil out is 110 F. The absorber pressure is 155 psig.

The feed to the debutanizer consists of the bottoms from the PD stripper. These are heated by heat exchange to 275 F. Butane and lighter leave the top of the tower at 138 F and are condensed and cooled to 97 F in the reflux drum. There are vapors popped from this drum through a back pressure regulator to the absorber. The tower base temperature is 445 F, and the pressure is 190 psig. A pump maintains circulation from the base of the tower to a direct-fired vertical heater that serves as the reboiler. The stream temperature out of this reboiler is 474 F. Reflux rate into the top of the tower is 162 gpm.

The overhead make from the reflux drum is pumped directly to the deethan-

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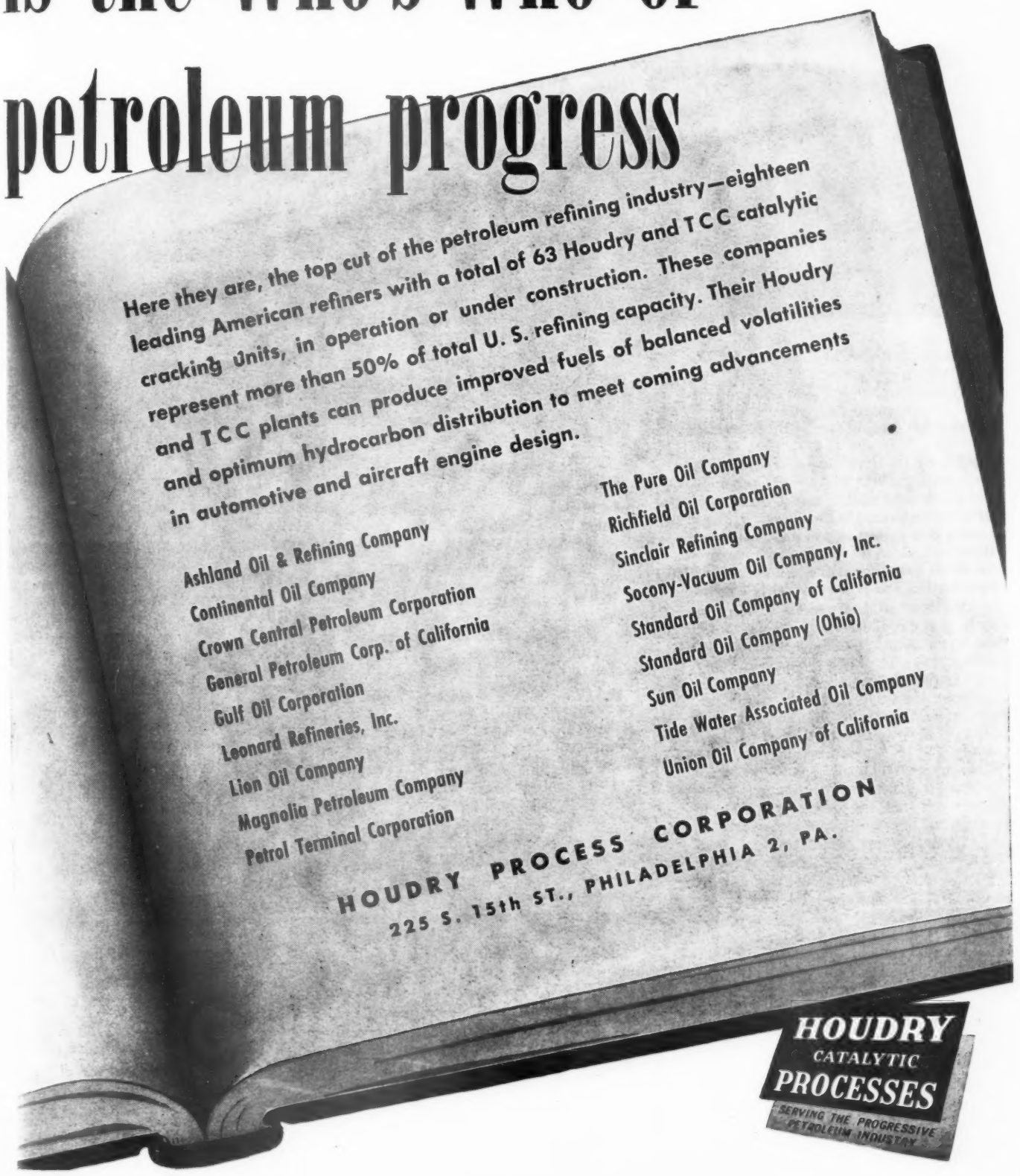
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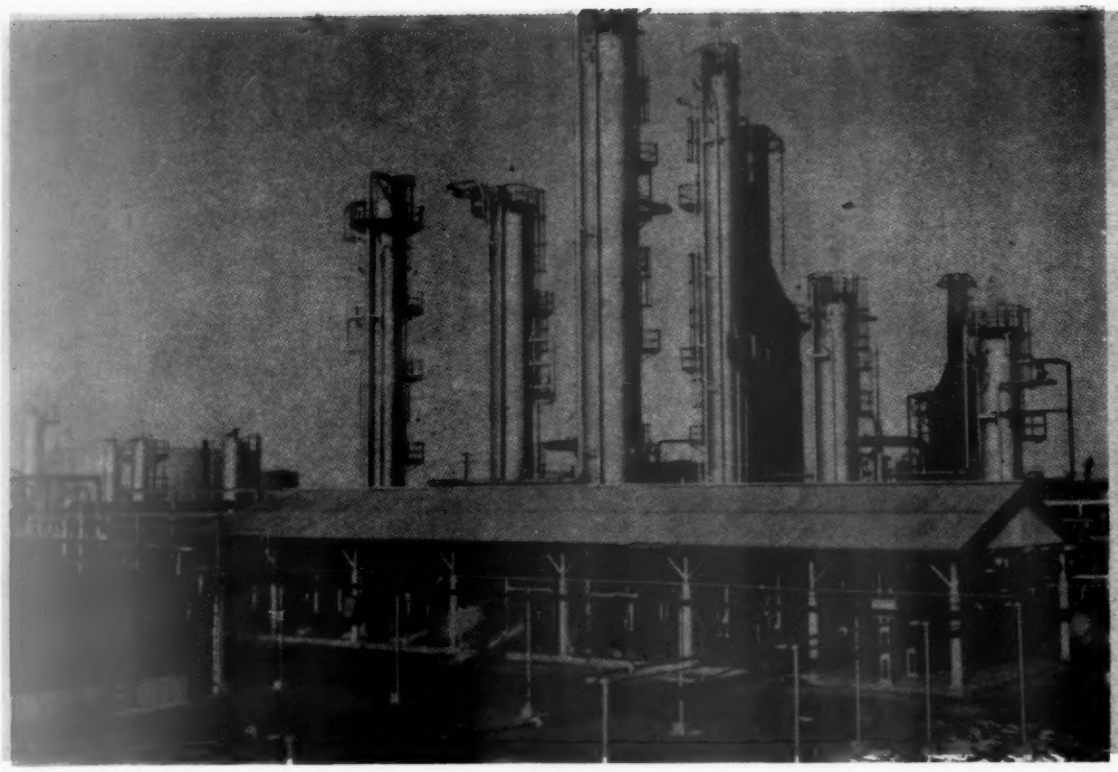

View showing reboiler heaters, towers, and one of the two pump sheds. The end of the coil pit is at extreme left.

izer tower without heat exchange. The deethanizer operates at 480 psig. The top tower temperature is 140 F, and the overhead is condensed and cooled to 110 F. All the liquid condensed is pumped back as reflux over the tower. This is controlled by the level in the reflux drum and runs at about 117 gpm. The vapors not condensed go through a back pressure regulator and to the absorber. These vapors can go to the residue or fuel gas if desired, since they contain 80 per cent or more of ethane and lighter. More than half of the H_2S removal is effected by this deethanizing operation. A pump maintains circulation from the bottom of the tower through a direct-fired vertical heater that serves as a reboiler and then back to the tower base. The heater outlet temperature is 216 F, and the tower base temperature is 212 F. The bottoms product rate of flow is controlled by the level in the base of the tower and pressures through caustic scrubbers to the polymerization plant. This bottom product is mostly propane, propylene, butanes, and butylenes. It is first scrubbed with a 12 Bé caustic solution, contacting the caustic through 15 ft of ¾-in. carbon Raschig rings. The C_3 and C_4's pass through an additional 5 ft of Raschig rings and 3 ft of tower space to separate from the caustic solution and then pass to the mercaptan scrubber. The first scrubber removes the hydrogen sulphide and was designed so that fresh caustic can be fed continuously into the top according to the amount needed, and spent caustic can be continuously drawn off at the bottom. It was decided to run batch method, however. Some H_2S may pass to the mercaptan scrubber, but caustic to recharge the H_2S scrubber is taken from the mercaptan scrubber and fresh caustic is always added to the mercaptan scrubbing system.

The C_3 and C_4's contact the caustic in the mercaptan scrubber countercurrently over 15 ft of ¾-in. carbon Raschig rings, and pass through an additional 5 ft of rings and 3 ft of space to separate from the caustic. The caustic is circulated from the bottom of the scrubber to a heat exchanger, preheater, and a regenerator, where, with live steam stripping and 250 F temperature at atmospheric pressure, the mercaptans are driven out the top and are piped to a knockout drum from which the vapors pass to a stack of one of the heaters. The regenerated caustic goes to the heat exchanger and a cooler, and is pumped over the top of the mercaptan scrubber completing its cycle. The C_3 and C_4's go to a caustic settler and then to a water wash tower, where it contacts water in a 15-ft bed of coarse gravel. The pH of the water is held as close to 7.0 as possible, adding sulphuric acid if necessary. The water is changed about once each 2 weeks. By running the water for longer periods of time contamination of C_3 and C_4's with the dissolved oxygen of the fresh water is avoided. By holding the pH of the water as near 7.0 as possible there is better removal of any ammonia (used for corrosion control on the crude units) from the C_3 and C_4's. The ammonia is washed out to prevent poisoning of the polymerization catalyst. The C_3 and C_4's pass through a back pressure regulator that holds a pressure of 200 psig on the scrubbers, which reduces the caustic carryover that resulted when much lower pressure was held on the scrubbers. The C_3 and C_4's then go to the polymerization plant for processing. The overhead from the polymer debutanizer is pumped back to the vapor recovery unit to the depropanizer tower. The feed is heated by heat exchange to a temperature of 150 F. The top tower temperature is 122 F, the base tower temperature is 224 F, and the tower pressure 250 psig. The reboiler is heated by steam controlled by the temperature in the base of the tower. The pressure on this tower and reflux drum is controlled by a valve in a bypass line around the overhead condensers. The reflux drum temperature is 118 F. Propane is the overhead product and butane is the base product. The butane pressures from the base of the tower to a heat exchanger to heat the feed. It then goes to a cooler, and then to storage. The propane from the reflux drum is pumped through a cooler and then to bauxite driers and then to storage. Two driers are used in series for drying, while one drier is on regenerating cycle. One drier would be sufficient most of the time, but a dry propane product is important enough to use two units to make certain.

A closed circulation of propane is used to regenerate the driers. Liquid propane from the settling drum is pumped

TABLE 1

	Propane	Butane
Vapor pressure at 105 F, lb	206	44
Mercury freezing residue	0	
95 per cent weathering test		31 F
Corrosion	None	None
Moisture	Dry to cobalt bromide test	None
Doctor	Sweet	Sweet

TABLE 2

	Gasoline	Absorption oil
RVP, lb	6.2	0.6
Gravity	57.5° API	47.4° API
Distillation:		
IBP	110 F	202 F
5 percent	127	235
10 per cent	141	247
20 per cent	162	310
50 per cent	249	394
90 per cent	381	409
EP	425	429

Name the problem—

- *High temperature*
- *Low temperature*
- *Product purity*
- *Corrosion resistance*

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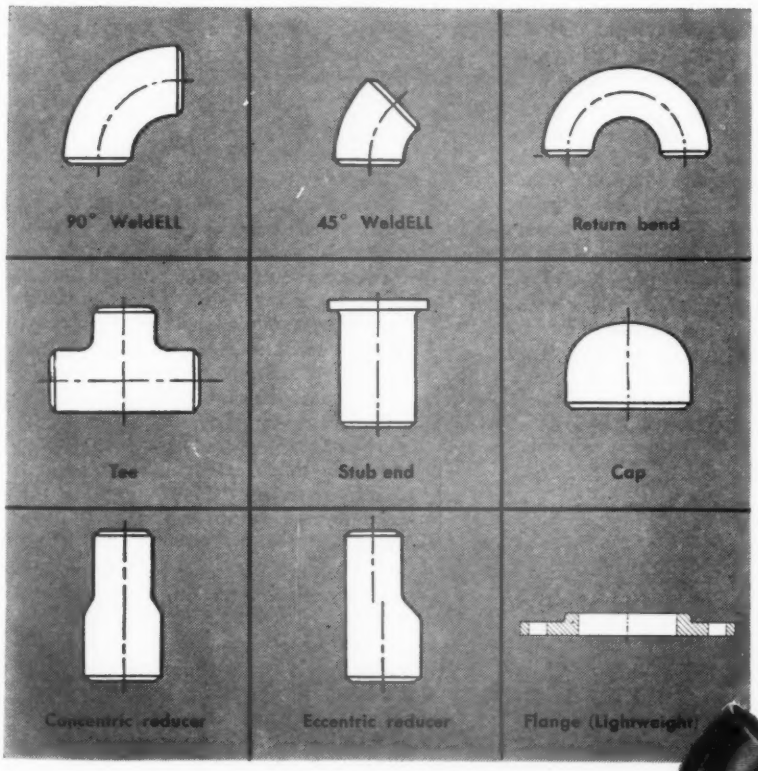

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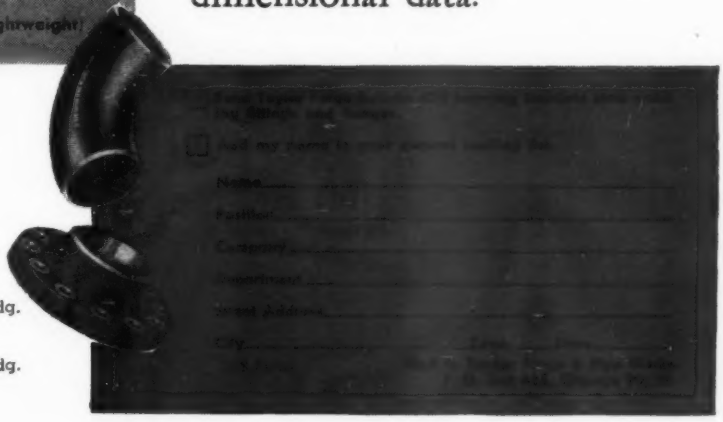

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TABLE 3. Material balance. Charge to vapor recovery unit, bbl per day.

	Thermal cracking		Rich oil from gas plant	Total feed	Absorber residue	PDstripper bottoms to debutanizer	PDstripper overhead to absorber	Debutaniser overhead vapors to absorber	Deethanizer overhead vapors to absorber	Debutanizer bottoms	Debutaniser overhead liquid to deethanizer	Deethanizer bottoms to polymerization	Polymer 10 lb RVP	Propane	Butane
	High pressure gas	Raw cracked pressure distillate													
C_1	458	47		505	505	19	115	11	8		8				
C_2	209	279	32	610	596	354	160	174	166		180	14		14	
C_3=	68	208	11	287	22	383	43	64	54		319	265		40	
C_3	123	435	111	669	30	799	98	124	36		675	639		629	10
C_4=	32	375	17	424		450	25	22	4	60	368	364	8		79
C_4	47	490	178	685		723	76	36	2	90	597	595	63		532
C_5	29	4728	1944	6701		10543	29	1	1	10541			419		
	1056	6532	2293	9881	1153	13271	546	432	271	10691	2147	1877	490	683	621
Less lean oil.....			1372	1372		5212				5212					
			921	8509		8059				5479					

through a small vertical direct-fired heater where it is heated to 350 F temperature. These heated propane vapors go to the drier being regenerated. The temperature out of the drier rises to about 240 F and levels at this temperature for a while, and then goes on to 350 F, at which time the fire in the heater is shut off and the circulation continues until the drier is cooled back to 110 F. The vapors from this drier go to a condenser and cooler and then back to the settling drum, from which the water removed from the drier is drained off. The complete cycle for regeneration of the drier takes from 6 to 8 hr.

The feed to this vapor recovery unit carries some water vapor and entrained water. This water concentrates mostly in the debutanizer reflux drum where it is drawn off. A small amount of water is drawn off from the deethanizer reflux drum also.

The deethanizer pressure control valve passes from 480 psig to 155 psig. This expansion causes cooling sufficient to drop out moisture and freeze it in the valve so the vapors to this valve are heated with steam to prevent freezing.

In the caustic scrubbing system caustic consumption is 20 lb of 73 per cent caustic per 100 bbl of C_3-C_4 mixture scrubbed. When the plant was first started a 22 to 25 Bé caustic was used in the mercaptan removal system, and a 15 Bé caustic in the H_2S removal system. It is found now that 12 to 14 Bé caustic is satisfactory in both the mercaptan and H_2S scrubbers, giving lower caustic consumption. At the start the caustic in the H_2S scrubber was replaced with fresh caustic when it was spent. It was found that the sodium sulphide content built up in the mercaptan system and then the freezing point of the solution raised to as high as 45 F in a 25 Bé solution. By charging the H_2S system from the mercaptan system and charging the fresh caustic to the mercaptan system, however, the freezing point of the solutions was lower than that of the same gravity of caustic solution. A 20 Bé solution in the mercaptan system had a — 20 F freezing point. The 12 Bé caustic has a freezing point of 10 F. So, for severe cold weather, a 20 Bé solution is used and during the rest of the year a 12 to 14 Bé solution is used for mercaptan removal. For H_2S removal a 15 Bé solution is used for cold weather and a 10-12 Bé solution for the rest of the year. Carbon steel with stress-relieved welds was used in this caustic scrubbing system, but there has been one failure of a weld in the preheater to the regenerator after eight months' service.

TABLE 4. Material balance. Low pressure gas recovery at gas plant.

	Low pressure gas from thermal cracking	Vapors from crude distillation and tanks	Total feed	Rich oil and condensate to vapor recovery unit	Absorber residue
C_1	72	6	78		78
C_2	78	38	116	32	84
C_3=	13		13	11	2
C_3	67	51	118	111	7
C_4=	18		18	17	1
C_4	57	122	179	178	1
C_5	67	505	572	572	
	372	722	1094	921	173

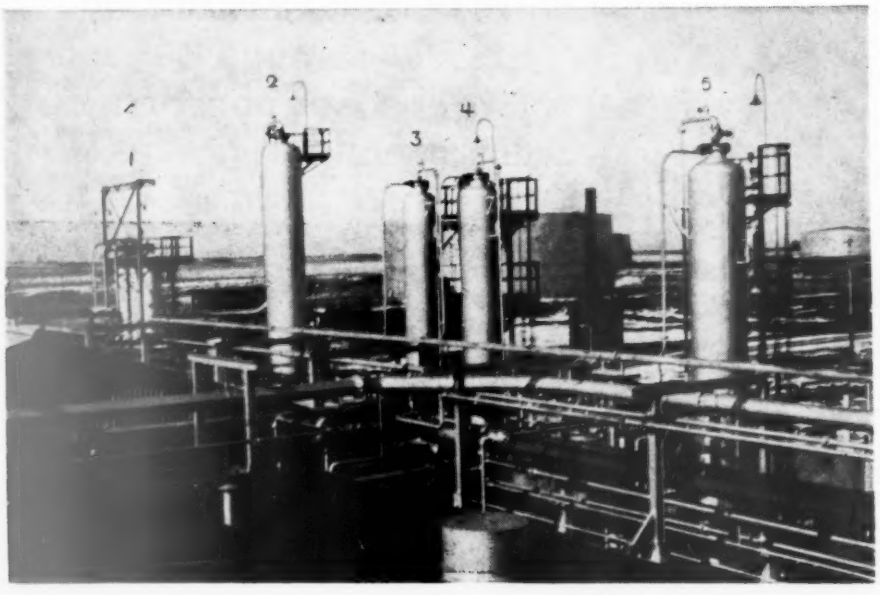
For absorption oil, a portion of the bottoms from the debutanizer is charged to the still where the bottoms are controlled to the desired initial boiling point. These bottoms are circulated over the top of the two absorbers as the absorption oil. The overhead fraction from the still is a light cut from the debutanizer bottoms. The debutanizer bottoms not going to the still and the still overhead fraction go together to a cooler and then to the treating plant and to gasoline storage. This completes the three product streams—propane, butane, and gasoline.

The laboratory tests of the three products and of the absorption oil are shown in Tables 1 and 2.

Table 3 gives a typical material balance for the new vapor recovery unit, and a material balance on the low pressure system at the old gas plant is given in Table 4.

The vapor recovery unit installed at Skelly Oil Company's El Dorado, Kansas, refinery has exceeded performance expectations; has provided materially increased recoveries of liquefied petroleum gas products, and polymer gasoline; and provided a cracked gasoline of exceptional front-end volatility characteristics. The unit has more than justified the original decision that the vapor recovery unit, as the first step in the modernization and expansion program, would provide the maximum benefit in producing the optimum yields of refined products from crude oil. ★★★

Numbers indicate: 1 propane driers, 2 mercaptan scrubber caustic regenerator, 3 hydrogen sulphide scrubber, 4 mercaptan scrubber, and 5 water wash tower.



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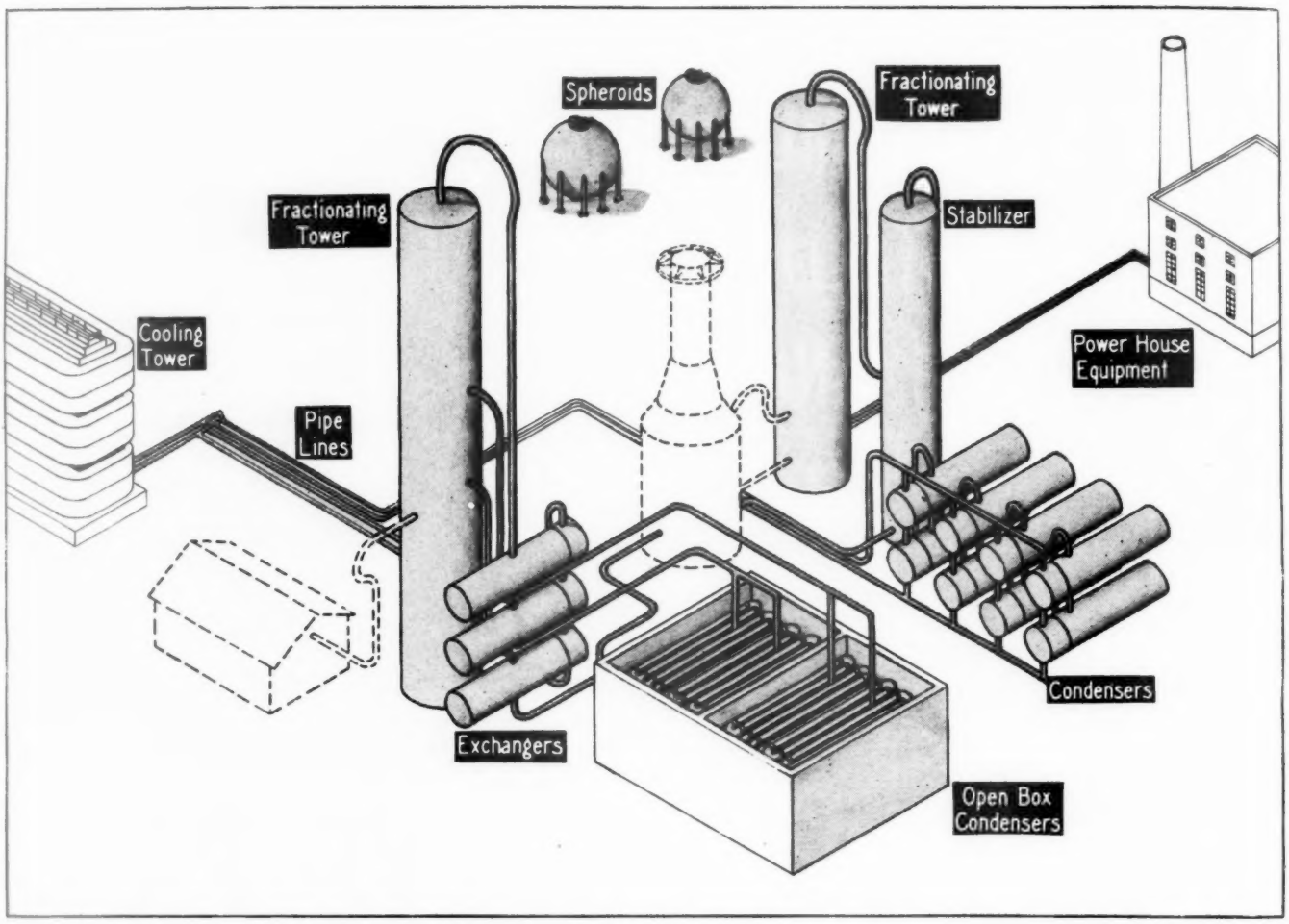

FIG. 1. Refinery equipment that can be chemically cleaned.

Chemical cleaning in the refinery

By C. H. GROOM, Dowell Incorporated

CHEMICAL cleaning comprises the removal of any undesirable deposit or coating from a surface through the use of chemical solvents. In a refinery the application of chemical cleaning can be a major factor in the restoration of designed unit efficiency and purity of product, also in the lengthening of operating periods, less frequent equipment inspections, and decreasing of maintenance.

EXCLUSIVE

Chemical cleaning has been successfully applied to practically every type of steam raising, heat exchange, transfer and storage in all refinery divisions. Fig. 1 illustrates the divisions and types of equipment in a refinery that can be chemically cleaned. In the power house the equipment consists of water treating units, filters, pumps, transfer lines, engine jackets, heaters, economizers, boilers, superheaters, and related units. Refinery cooling water systems with their coils, collecting and distributing lines are particularly adapted to chemical cleaning as it eliminates dismantling. Open box condensers, tube and shell units, and practically all water handling equipment can be chemically cleaned. In the process equipment of a refinery, towers of all types are quickly and effectively cleaned as well as tube and shell units, lines and storage facilities.

Chemical cleaning must be based upon a consideration of three factors. These are: (1) The deposit to be removed; (2) the solvent to be used, and (3) the unit to be cleaned. Each of these factors has its own associated properties and problems discussed in detail in subsquent sections of this article.

● **Deposits encountered.** The deposits encountered in refinery equipment fall into three classes. These are inorganic materials, organic materials, and mixtures of both. Inorganic deposits are associated with equipment handling water and are laid down either by deposition from the water or by corrosion of the metal, or both. Organic deposits are encountered in the process sides of refinery equipment. They are formed by the decomposition and polymerization of petroleum hydrocarbons on the contact surfaces of the units. Mixtures of organic and inorganic deposits also are encountered in the process sides of refinery equipment with the inorganic portions generally composed of iron oxides and sulphides, copper oxides and sulphides, and other metallic salts.

The nature of the deposit, inorganic,

organic or mixtures of both, dictates the type of solvent adaptable to removing it. The solvent associated with inorganic scale removal is hydrochloric acid in concentrations of 5 to 15 per cent by weight. Various modifications of the acid may be obtained by the addition of wetting and emulsifying agents and intensifiers or catalysts. Solvents associated with the removal of scale deposited from process materials include hydrochloric acid, alkaline solutions, detergents, hydrocarbon solvents, chlorinated hydrocarbons, and oxidizing solutions.

As described above chemical cleaning is adaptable to the equipment in practically every division of the refinery. The unit to be cleaned enters into the calculations concerning chemical cleaning as its design, its size in respect to surface area and volume, the metals from which it is fabricated and the service it is in all must be considered. Each of these factors contributes to the type, concentration and amount of solvent and the conditions under which it can be applied.

● **Water side deposits.** A sample of the scale must be obtained from the unit to be cleaned that is representative of the bulk of the scale. The location of the scale sampled and the manner of sampling are important as the sample must represent the scale deposit down to the bare metal. This sample then may be analyzed by the most convenient methods available. Simple qualitative chemical tests are sufficient to identify the deposit as to carbonates, phosphates, oxides, sulphates or silicates. The exact structural grouping of the components is not essential as the primary radicals dictate the chemical reactions involved. (See Table 1.) The carbonates, phosphates, and iron oxides react with hydrochloric acid forming soluble salts. The silicates are rendered soluble through the addition of intensifiers to the acid solution. The sulphates are only partially soluble. In most instances, however, the silicates and sulphates are contained in mixtures with the acid soluble carbonates, phosphates, and oxides. Thus the removal of the acid soluble constituents usually effects the removal of the silicates and sulphates that are present. Scale deposits consisting primarily of silicates or sulphates are removed by alternate applications of alkaline and acid solutions.

The amount of hydrochloric acid required to remove the above-mentioned scale deposits is proportional to the amount of scale present. The average thickness of the scale times the area of the scaled surface give the total amount of scale present in the unit. Table 2 lists the basic amounts of hydrochloric acid required to dissolve the types of inorganic scale deposits most frequently encountered in refinery equipment.

● **Process side deposits.** Similar to water side deposits, process side deposits must be identified but, unlike water side deposits, the identification is of a general nature, influenced greatly by the experience of the chemist. A process side deposit generally is identified by breaking it down into three rough classifications: oil soluble, oil insoluble, and inorganic. The oil soluble component of the sample is determined by extraction with carbontetrachloride, the inorganic component by the unignitable portion of the sample, and the oil insoluble component by difference. From the sample's physical appearance the oil insoluble component is described as being slightly polymerized, highly polymerized or carbonized. The term, "polymerized", is used loosely to designate the magnitude of the material's molecular weight. The inorganic components of the scale generally are composed of the oxides and sulphides of iron, copper and zinc. Typical process side deposits are described in Table 3.

TABLE 1. Chemical reaction of hydrochloric acid on inorganic scale deposits.

$FeO+2\ HCl$	$=FeCl_2+H_2O$
$Fe_2O_3+6\ HCl$	$=FeCl_3+3\ H_2O$
$Fe_3O_4+8\ HCl$	$=2\ FeCl_3+FeCl_2+4\ H_2O$
$FeOOH+3\ HCl$	$=FeCl_3+2\ H_2O$
$Cu_2O+2\ HCl$	$=2\ CuCl+H_2O$
$CuO+2\ HCl$	$=CuCl_2+H_2O$
$FeS+2\ HCl$	$=FeCl_2+H_2S$
$CuS+2\ HCl$	$=CuCl_2+H_2S$
$ZnS+2\ HCl$	$=ZuCl_2+H_2S$
$CaCO_3+2\ HCl$	$=CaCl_2+H_2O+CO_2$
$Ca_{10}(OH)_2(PO_4)_6+20HCl$	$=10\ CaCl_2+2\ H_2O+6H_3PO_4$

TABLE 2. Basic amounts of hydrochloric acid required to dissolve inorganic scale deposits.

Deposit	Formula	Gal of 15 per cent HCl* per cu ft of deposit
Ferrous oxide	FeO	252
Ferric oxide	Fe_2O_3	399
Iron oxide hydrate	$FeOOH$	230
Ferrous-ferric oxide	Fe_3O_4	343
Cuprous oxide	Cu_2O	133
Cupric oxide	CuO	255
Iron sulphide	FeS	181
Copper sulphide	CuS	152
Zinc sulphide	ZnS	134
Calcium carbonate	$CaCO_3$	93
Calcium hydroxy phosphate	$Ca_{10}(OH)_2(PO_4)_6$	105

*Based on maximum density. The deposits generally have considerable porosity and the amount of acid required is less than that listed.

TABLE 3. Typical process side deposits.

Service	Deposit
Depropanizer	Polymerized organic with considerable iron oxides.
Fractionator	Mostly iron oxides with small amount of organic. Some iron sulphide.
Absorber	Mostly iron oxides intimately mixed with oil.
Light oil exchanger	Highly polymerized organic with small amount of iron oxides.
Catalyst coolers	Intimate mixture of equal amounts of oil and iron oxides.
Catalytic cracker partial condenser.	Intimate mixture of iron oxides, iron sulphides polymerized organic and oil.
Ammonia condenser	Mostly iron oxides with small amount of oily sludge.

FIG. 2. Mobile mixing and pumping equipment designed for chemical cleaning.

● **Application of the solvents.** The effectiveness of any chemical solvent is determined by four factors. These are: (1) Concentration of the solvent, (2) temperature of the solvent, (3) agitation of the solvent, and (4) contact time of the solvent. In general, increasing any one of these factors will increase the effectiveness of the solvent. The magnitude of each, however, has a limiting factor. The degree of concentration of the solvent must be controlled by costs and corrosion hazards which may be involved. Agitation is controlled by the volume of solvent involved in relation to the size of the pumping equipment and service lines required to give good movement of the fluid by circulation. The temperature to be used is limited almost entirely by corrosion hazards. The time element is limited by extension of down time with its accompanying costs, also by corrosion hazards. Consideration of these four factors indicates that the criterion for successful chemical cleaning should be the use of the lowest concentration of solvent at the

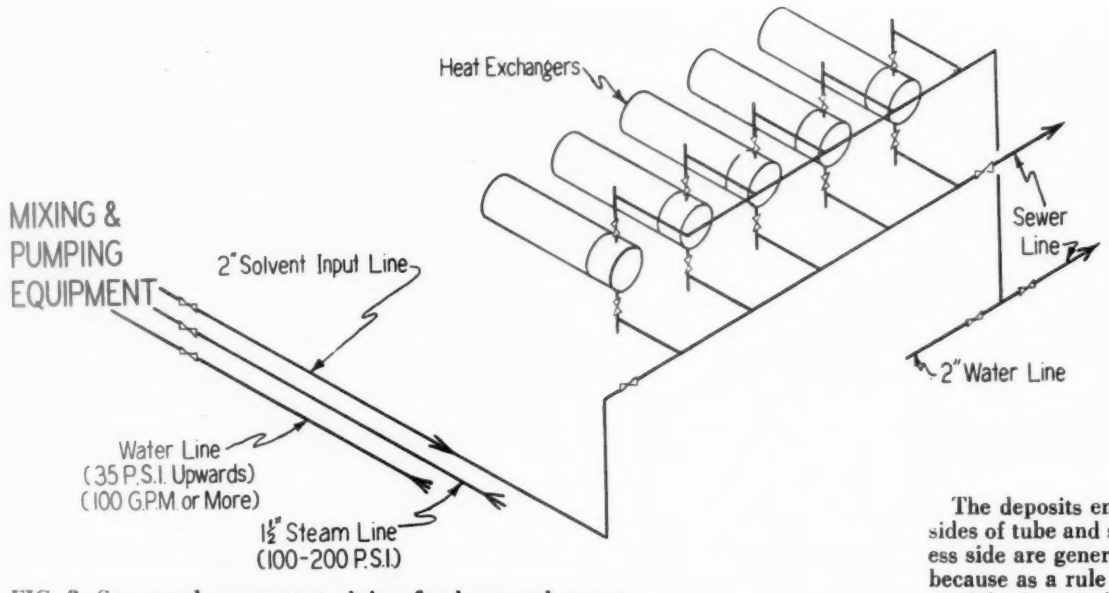

FIG. 3. Suggested permanent piping for heat exchangers.

lowest temperature for the shortest time necessary to remove the scale deposits.

In the preparation of hydrochloric acid solutions for chemical cleaning it is advantageous to have available portable equipment, which includes solvent storage and pump units as illustrated in Fig. 2. The acid is most economically transported in concentrated solutions, containing the inhibitors and essential addition agents. This concentrated solution then is diluted with water as it is used by means of specially designed proportioning equipment. The acid solution is heated prior to entering the unit by means of a portable jet heater. The alkaline type and hydrocarbon type solvents used in process side equipment require practically the same handling. A small mixing tank may be added for the dissolving of the various solids and liquid agents as needed.

The available solvent discharge and return lines greatly affect the application of the solvent in that they govern the rate and safety at which the solvent can be handled. The best lines consist of 2-in. steel pipe. Due to the extensive areas over which various refinery units are distributed, piping is somewhat expensive, but if the piping is installed as permanent chemical cleaning equipment the cost is minimized. Fig. 3 illustrates a suggested permanent piping on tube and shell units to provide for chemical cleaning. It is elaborate but it enables the individual cleaning of any one unit, also allows ease of flushing and back flushing the units. Less elaborate modifications of this hookup will be found more practical on some installations. Where scattered, small volume units are involved, hose is applicable. In this regard, about the largest size hose, safe for handling the solvents at the pressures and temperatures involved, is 1¼ in. ID. Where it is necessary to use hose, the same sections of hose can be transferred from one unit to another.

The necessary solvent temperature is obtained by jetting steam directly into the solvent except when a non-miscible solvent is used. Hydrochloric acid always should be heated only by venting steam directly into the sections. It never should be heated by applying steam to the opposite side of the unit (that which does not contain acid during the cleaning operation) as the inhibitors will not protect effectively the metal on the acid under these conditions. The alkaline solvents may be heated either directly by injecting steam into the solvent or by any source of heat on the side of the unit not containing the solvent during the cleaning process.

Agitation of the solvent during the cleaning operation generally is obtained by recirculation as other means of agitation would require elaborate equipment either within or on the unit being cleaned. The main purpose of this agitation is to keep solvent of the desired concentration and temperature in contact with the scale deposit. Agitation by recirculation is necessary on inorganic deposits only where the unit volume is such that the ratio of solvent to scale deposit is low, as in heat exchanger tubes. Then it is only necessary to displace the spent solvent with fresh solvent at intervals. In the removal of organic deposits some type of agitation usually is required throughout the entire operation, either by recirculation, steam, air, or gas. This is due primarily to the fact that organic deposits generally are removed by dispersal in the solvent rather than entering into solution.

● **Summary.** In general, practically any inorganic scale deposit can be removed chemically, provided enough solvent and time are used; however, there are instances where the amount of solvent would be so great as to render the operation uneconomical. Any process side unit fouled with iron oxides and sulphides can be chemically cleaned and it may be said that, except for the highly carbonized deposits, most of the process side deposits also can be removed with chemical solvents.

The deposits encountered in the shell sides of tube and shell units on the process side are generally difficult to remove because as a rule the units are operated until the deposits become thick and crack off the tubes. The loosened deposits fall down into the bundle completely filling the annular space between the tubes, resulting in higher operating temperatures and causing carbonizing of the deposit to a high degree. In such circumstances there is no fluid passage remaining between the tubes and the chemical solvent merely skirts the bundle, cleans up the periphery, and never enters the bundle to any appreciable depth. The shell sides of units with relatively low operating temperatures probably could be cleaned effectively if they were operated for shorter times between the cleanings. But, even on those bundles that are tightly packed with scale, chemical cleaning can be used to an advantage in that the proper solvent will clean the periphery of the bundle allowing it to be pulled easily. Also application of the proper solvent when the bundle is in place results in changing the chemical and physical properties of the deposits so that they can be removed readily by hosing or mechanical means. As mentioned previously, highly carbonized scale deposits do not respond to the practical chemical solvents.

The use of solvents in cleaning refinery equipment is an additional tool for production and maintenance in the refinery. By recognizing its proper application and its limitations it is probably the easiest and most economical aid to efficient production and maintenance that is readily accessible to the refinery. An engineer trained in the recognition of the deposits, selection of the solvents and their application, using suitable equipment can perform a large amount of work in a relatively short time resulting in increased efficiency and economy of operation.

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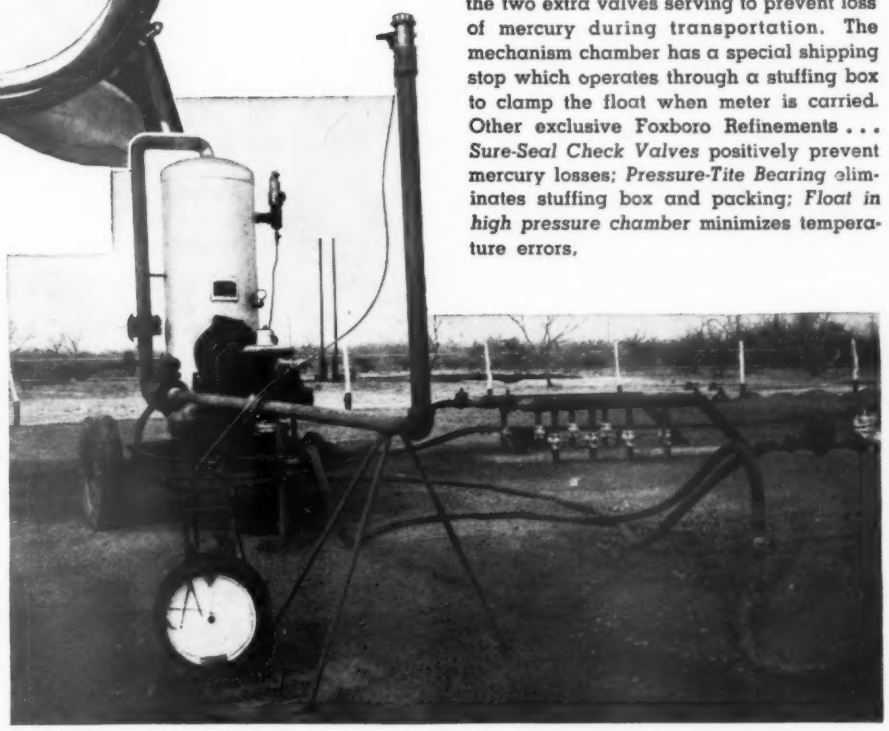

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Get all the facts about the unique and exclusive features of this flow meter. Write **The Foxboro Company, 130 Neponset Avenue, Foxboro, Mass., U. S. A.**

FOXBORO
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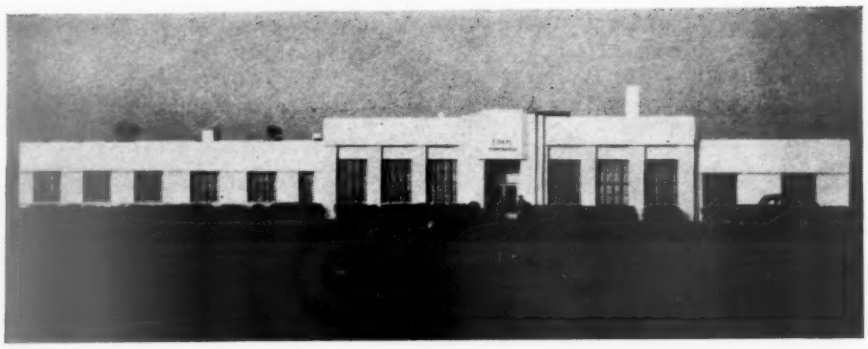
DIFFERENTIAL-TYPE FLOW METERS



Road testing laboratory of Ethyl Corporation in California.

Research by the mile*

MORE than six and one-quarter million miles—or 253 trips around the world at the equator. That's the distance road research crews of the Ethyl Corporation Research Laboratory at San Bernardino have traveled in the 13 years that research plant has been functioning.

EXCLUSIVE

*Written by staff of Ethyl Corporation, New York, N. Y.

This staggering amount of driving—an average of 520,000 miles yearly—is a vital part of the laboratory's year-round program of road and laboratory research on engines and motor fuels.

Because of the ideal weather conditions that prevail in Southern California throughout the entire year, most of Ethyl Corporation's road research operations are conducted at San Bernardino. A fleet of vehicles is also maintained at the Ethyl Research Laboratories in Detroit, however.

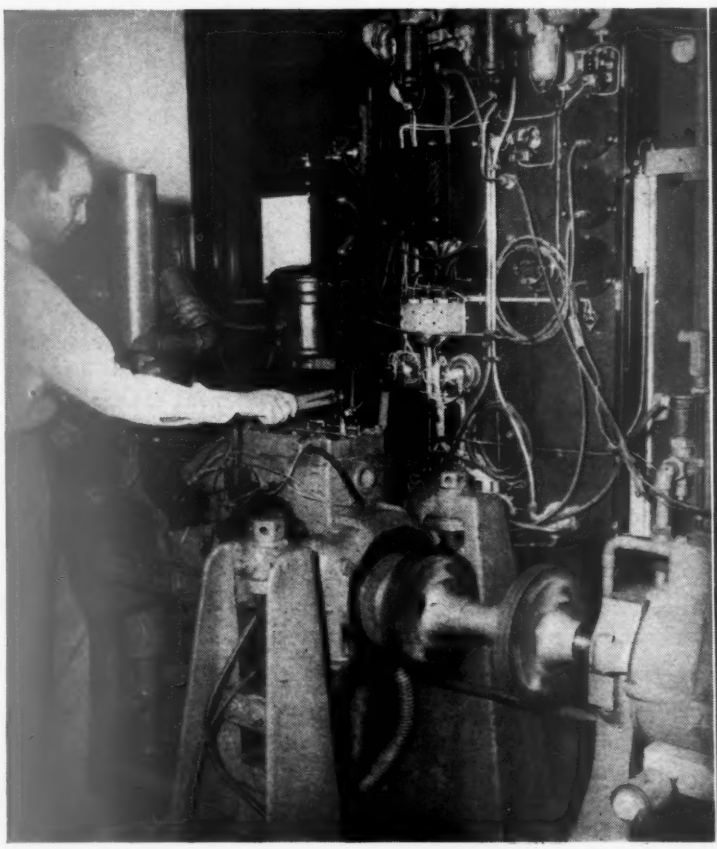
So far as highway terrain and road and weather conditions are concerned, a "United States in miniature" exists in the immediate San Bernardino area. It was chiefly because of this fact that Ethyl Corporation back in 1935 decided upon that city as the site of the laboratory it was contemplating at that time.

At the laboratory are complete facilities for road research on the interdependent problems of engines, fuels, and lubricants. Representative of the modern laboratory pieces of equipment on hand is the chassis dynamometer. This modern device permits the indoor operation of an automobile, truck, or tractor under virtually the same conditions as would exist on the highway or farm.

Basically, the chassis dynamometer consists of an electric generator and a set of rollers. The latter support and are rotated by the rear wheels of the test vehicle to simulate actual driving. The electric generator is connected to the rollers, and thus provides a "load" to be driven by the rear wheels of the vehicle. The amount of this "load" can be adjusted to any desired value in order to simulate any type of driving, from operation on a level road to that up the steepest mountain grade.

The electric generator of the dynamometer also can be operated as a motor, so that it will rotate the vehicle's rear wheels and thus drive the engine to permit measurement of compression pressures, engine friction, etc. The dyna-

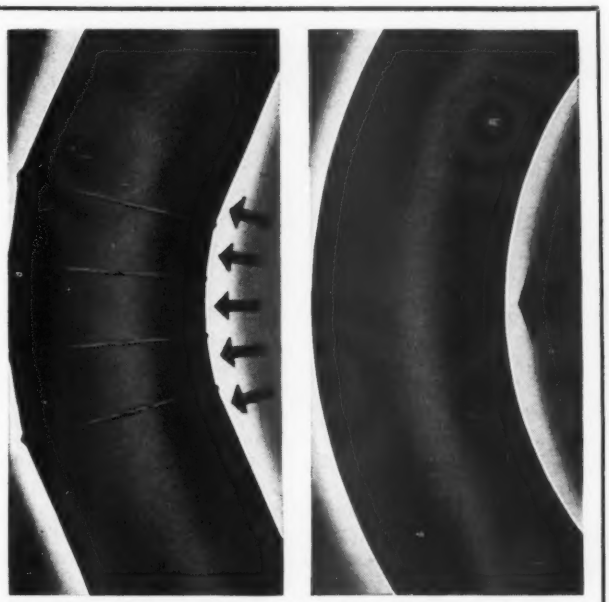
Spark plugs are checked during actual operation.



Control panel for testing engine on dynamometer.

NEW KELLOGG PROCESS MAKES GIANT PIPE BENDS *In one piece!*

Avoids corrosion and erosion due to stress intensification . . . applicable to pipe up to 8 feet in diameter



In pipe larger than 34 inches in diameter, bends have customarily been made by welding several segments together (left). The non-uniform contour of such welded bends increased erosive effects of flowing material because of the abrupt changes in direction of flow. In addition, a serious phenomenon, known as stress corrosion developed at or near weld seams. The smooth contour of the new Kellogg one-piece bends reduces the factors of erosion and corrosion to a minimum.

M. W. KELLOGG engineers have perfected a method and apparatus for bending, *in one piece,* pipe large enough to hold a limousine!

By eliminating the need for welded segments, the new process permits smoother, more uniform flow of fluids . . . reduces erosion and wear to a minimum, particularly where powdered catalysts are utilized.

Through an ingenious application of heat and hydraulic pressure, large diameter pipe is bent in continuous incremental stages without buckling or creasing. The process is adaptable alike to small and large diameters, to thin and thick-walled pipe, and to short and long radius bends.

Exhaustive tests and analyses of 50-inch pipe, currently being fabricated in the Kellogg Shops, prove that the new weldless, one-piece bending process produces results superior to any previously obtained.

It's this constant striving for improvement that accounts for Kellogg's position in petroleum engineering . . . the reason why so many of the world's foremost petroleum companies turn to Kellogg when top performance is all-important.

THE M. W. KELLOGG COMPANY

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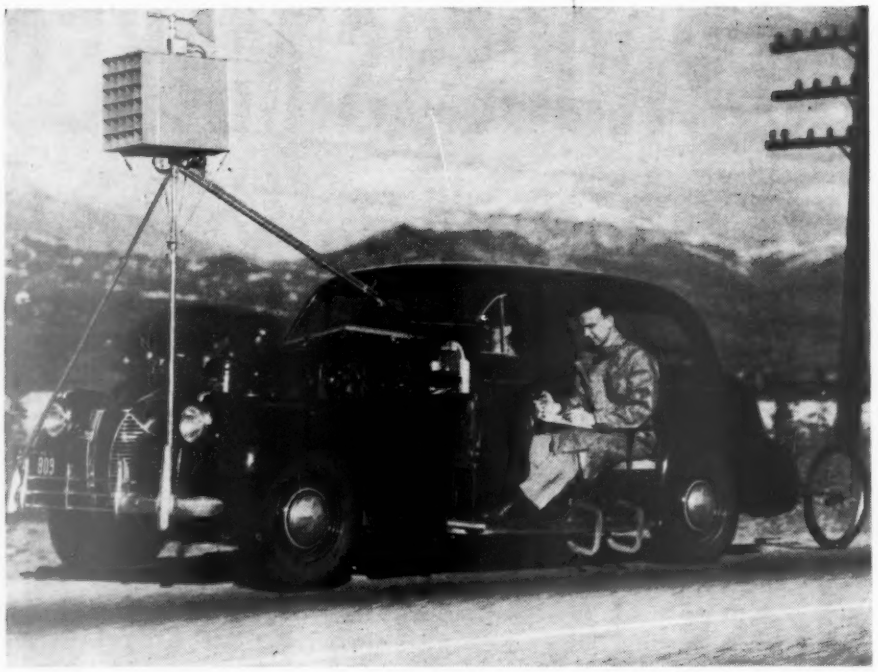


Special test equipment mounted on the car permits evaluation of gasoline performance on the road at all driving speeds. In San Bernardino cars can be tested at all altitudes ranging from sea level to 6000 feet.

mometer is equipped with instruments for measurement of the power output of the vehicle, or the power absorbed by friction, if the vehicle is being driven by the dynamometer. Blower equipment in connection with the chassis dynamometer is capable of producing an air blast of as much as 85 mph against the front of a vehicle during tests.

Engine dynamometers also are available for certain engine and fuel studies that can be made to better advantage in the laboratory than on the road.

In addition to the research apparatus, the laboratory has complete facilities for conducting standardized fuel inspection tests.

A host of factors govern the performance of fuels in an engine on the road, and the compatibility of the fuel with the engine and its many separate parts. Even two brand-new cars of the same manufacture and model may act differently once out of the showroom. Atmospheric temperature, pressure, and humidity, engine speed and throttle opening, wind velocity, and road gradient all contribute to the performance of a vehicle. Also to be taken into account are road and traffic conditions, and the habits and driving whims of the individual driver.

Road research, as conducted with the laboratory's present fleet of seven truck-and-trailer units and ten passenger cars of different makes and models, is an essential part of the procedure for evaluating experimental gasolines and for determining the durability and endurance of various engine parts.

One type of program is conducted through the use of vehicles operated on gasolines blended with experimental mixtures of Ethyl brand of antiknock compound, or with experimental fuels, either treated or untreated with Ethyl antiknock compound. In research on engine endurance, several types of tests are conducted. One such highway research program calls for the installation, in alternate cylinders, of standard and experimental parts of different design and structure.

In any type of program, the same general pattern is followed.

A new car or truck is employed, because older vehicles might not be capable of the tremendous mileage that has to be traveled. After the vehicle has been broken in properly, its engine is torn down and then reassembled to include the specific engine parts of interest to the test.

The vehicle is driven 24 hours a day, every working day, with the same fuel and oil until a minimum number of parts being studied fails. In some cases, automobiles have been driven more than 200,000 miles without sufficient part failure to end the tests. The vehicle operating conditions are as representative as possible, and engineering tests are conducted periodically in order to compare the vehicle's performance at various stages of the research program.

It is this research—conducted day and night, in mountain cold and desert heat, and on straightaways and 12-deg climbs—that enables the Ethyl laboratory to suggest to the automotive industry possible design and structure changes that will give added durability to engine parts. These tests also provide valuable data in connection with Ethyl's never-ending research to improve Ethyl antiknock compound, if possible, and in connection with the antiknock quality requirements of gasoline as dictated by the engine and its parts.

During the recent war, the laboratory undertook many programs in behalf of the armed forces. For example, most of the 546,520 miles covered by the Ethyl road research vehicles in 1944 related to a study designed to improve the operation of the engines of Army trucks. Supplementing the laboratory and highway research activities, more than half of the San Bernardino technical employes served as wartime instructors and consultants on engine, fuels, and lubricant problems for the Army at Camp Seeley and Camp Young.

In addition to its road research activities, the San Bernardino laboratory houses one of Ethyl Corporation's five gasoline testing laboratories, located in five cities, that serve oil companies from coast to coast. Samples of gasoline are gathered from oil refineries, bulk plants, and service stations.

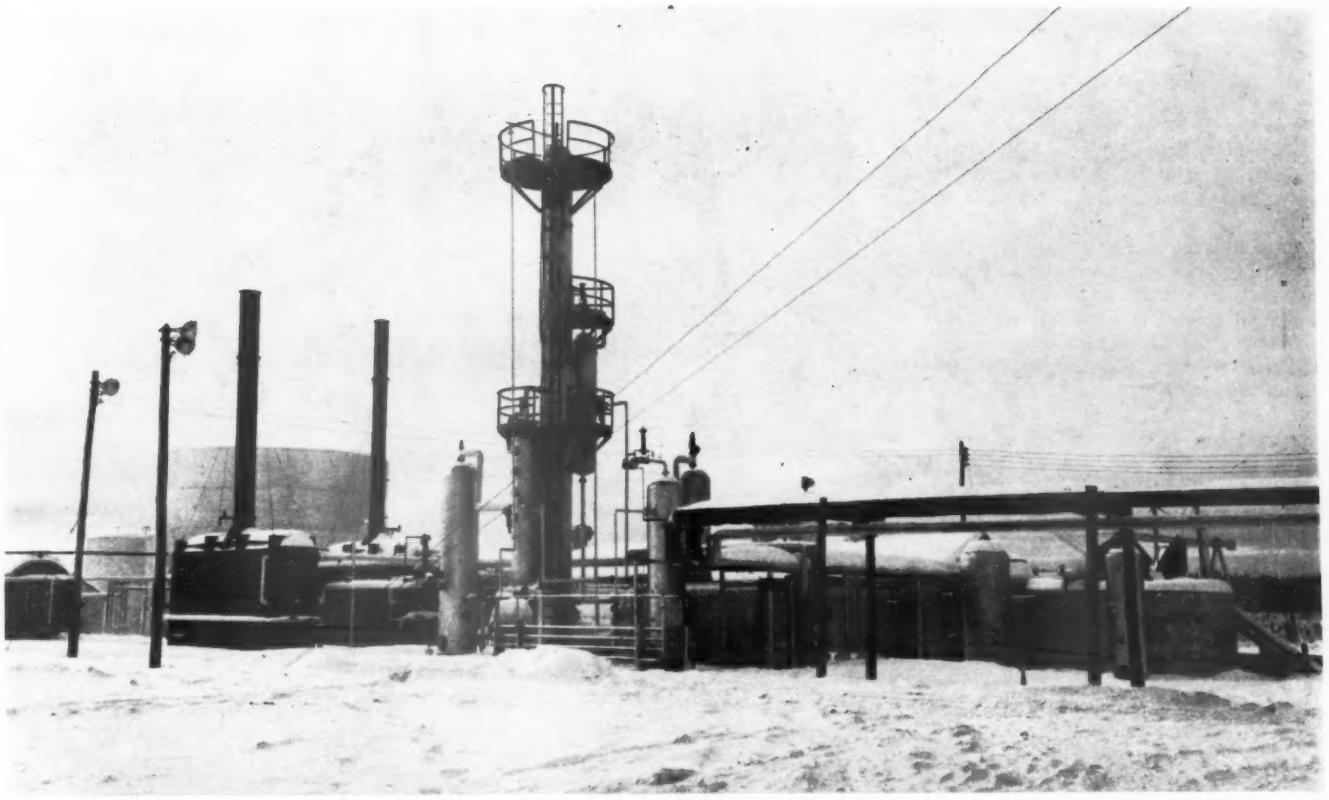
The refinery samples are examined primarily to insure that gasoline containing Ethyl antiknock compound conforms to the standards established for it. The field samples provide a spot-check on the quality of the gasoline as it is sold to the public. Oil companies are notified immediately of the results of individual analyses, as an aid to them in controlling the quality of their gasoline blends.

Situated on a 25-acre plot, the laboratory building is T-shaped, allowing for expansion in three directions. The office wing provides offices and drafting rooms for the technical staff, as well as rooms for technical files and photographic processes. The engine testing and fuel testing wing contains complete fuel inspection facilities equipped with standard single cylinder engines and one stand for multicylinder engines, and chemical apparatus. Other rooms are equipped for exhaust gas analysis, ignition research, and instrument calibration.

The third wing contains the garage, fuel blending equipment, chassis and engine dynamometers and associated equipment, and the machine shop. Fifteen underground gasoline storage tanks of more than 56,000-gal total capacity are tied into a central fuel blending system, and eight gasoline pumps in the garage dispense various types of fuel to the road research vehicles. A special building is equipped for the precision blending of fuels in quantities of 100 gal or less. All offices and fuel inspection laboratory areas are air conditioned.

When the present laboratory building was completed and occupied in October, 1938, Ethyl announcements described the San Bernardino facility as "a tangible expression of a conviction that the next ten years will bring the greatest progress yet seen in the development of fuels and engines."

On the basis of recent progress in engine design and petroleum refining technology, Ethyl Corporation renews that belief to apply to the next ten years. The San Bernardino laboratory will play an important part in this foreshadowed next decade of motor transportation progress. ★★★



Refining area, looking toward the southwest.

New plant to process Athabaska oil sands

By W. E. ADKINS, *Superintendent*, Oil Sands Limited

● **Introduction.** Due to current shortages of petroleum products "substitute" or "auxiliary" petroleum reserves are much in the news these days. Research directed at the production of petroleum products from coal, natural gas, oil shales, etc., has been accelerated tremendously in all parts of the world and with growing prospects of economic success. Heretofore these sources of petroleum products have been looked upon as reserves that might be utilized in cases of extreme national need such as a war might create, or at some time in the future when present oil fields are depleted. That utilization may be much closer is now evident and rising crude oil prices will certainly hasten developments.

EXCLUSIVE

As the possessor of the world's largest and most easily developed substitute petroleum reserve, the fabulous Athabaska oil sand deposits, the Government of Alberta, is taking a large, if not widely publicized part, in the effort to provide a new source of petroleum products.

For years the Athabaska oil sands, have dangled a plum of incomprehensible proportions before the eyes of oilmen from all over the world, but to date it still remains to be picked. Although it is true that a few people have been able to extract oil from the sands satisfactorily and in commercial quantities, none of them was able to achieve a "continuity" of operation that would enable them to determine satisfactorily the economics of the process. Much has been written and published regarding these spasmodic operations and it is amazing how readily oil experts have seized upon the incomplete data presented in these publications to condemn the oil sands as a source of petroleum because of the high cost of extraction that seemed to be indicated. Many estimates have been made of the probable cost of extraction. These range from 50 cents to $1.00 per bbl and appear conservative enough for anyone's satisfaction, but operating data have always contained too many "ifs" to substantiate the preliminary estimates to a considerable degree.

ALBERTA GOVERNMENT PHOTOS.

It is the purpose of the present project to achieve a continuity of operation that will allow a complete and accurate study of the economics of the process as well as to obtain heretofore unavailable operating data that will be necessary before large commercial units can be built and operated.

What the successful culmination of these investigations would mean to Canada's oil industry can be seen when it is remembered that these deposits contain four or five times as much oil as the present combined world reserves. Canada imports at present 90 per cent of her crude requirements and recent hints that the United States may curtail crude exports coupled with the current foreign exchange headaches that we are experiencing in this country gives added importance to the project.

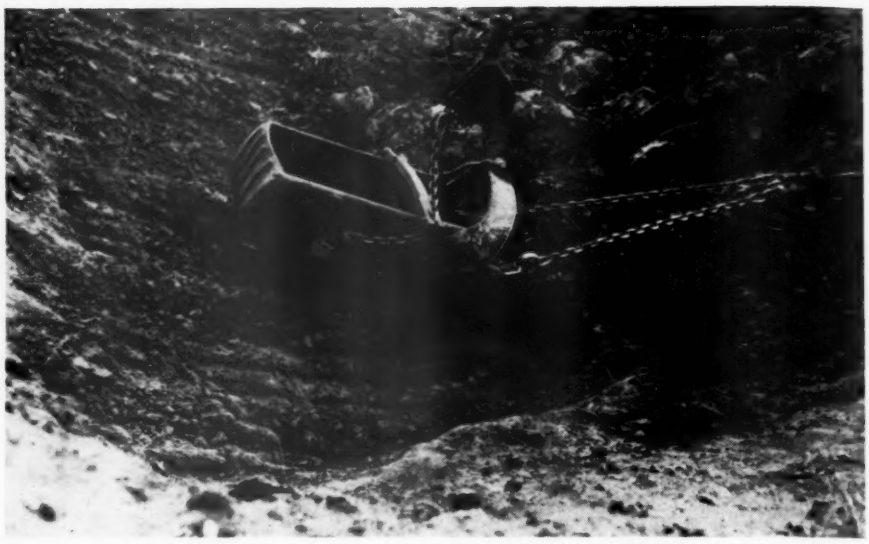
The Alberta Government plant, which is rapidly nearing completion at Bitu-

mount, Alberta, is based on laboratory investigations made by the Research Council of Alberta and plant operations conducted by Oil Sands Limited. Working from these data the Born Engineering Company of Tulsa, Oklahoma, designed all the process equipment. Although the separation plant and refinery, which will be operated in conjunction with it, will be capable of producing approximately 2,000,000 gal of finished products annually, the operation is not aimed at being commercial but primarily at the obtainment of cost and operating data.

The size of the separation unit (350 bbl per stream day) was chosen as the transition point between pilot plant and commercial operations. It was felt that if operations were conducted on a smaller scale it would be difficult to extrapolate operating data to large scale proportions.

● **Deposits.** Although some of the oil sands deposits are overlaid by heavy overburden, there are large tracts with oil content estimated at several billions of barrels where overburden is very light and can easily be removed by dragline, bulldozer, or similar means. At Bitumount, approximately 55 miles north of Fort McMurray, conditions exist that are ideally suited to development. Overburden is light, the saturation is high, and the beds are relatively thick. The Devonian lime on which the sand is deposited forms a deep syncline at this point and test wells indicate several hundred feet of oil sand.

Before actual construction began, test shafts were sunk to determine the best possible location for the mine. The site finally chosen is on top of the river bank approximately 65 ft above water level. The steep bank exposes oil sand over almost its entire height and a test well at water level showed another hundred feet of good grade sand. Samples taken from top to bottom of the exposure indicate an average saturation of 15 per cent by weight.



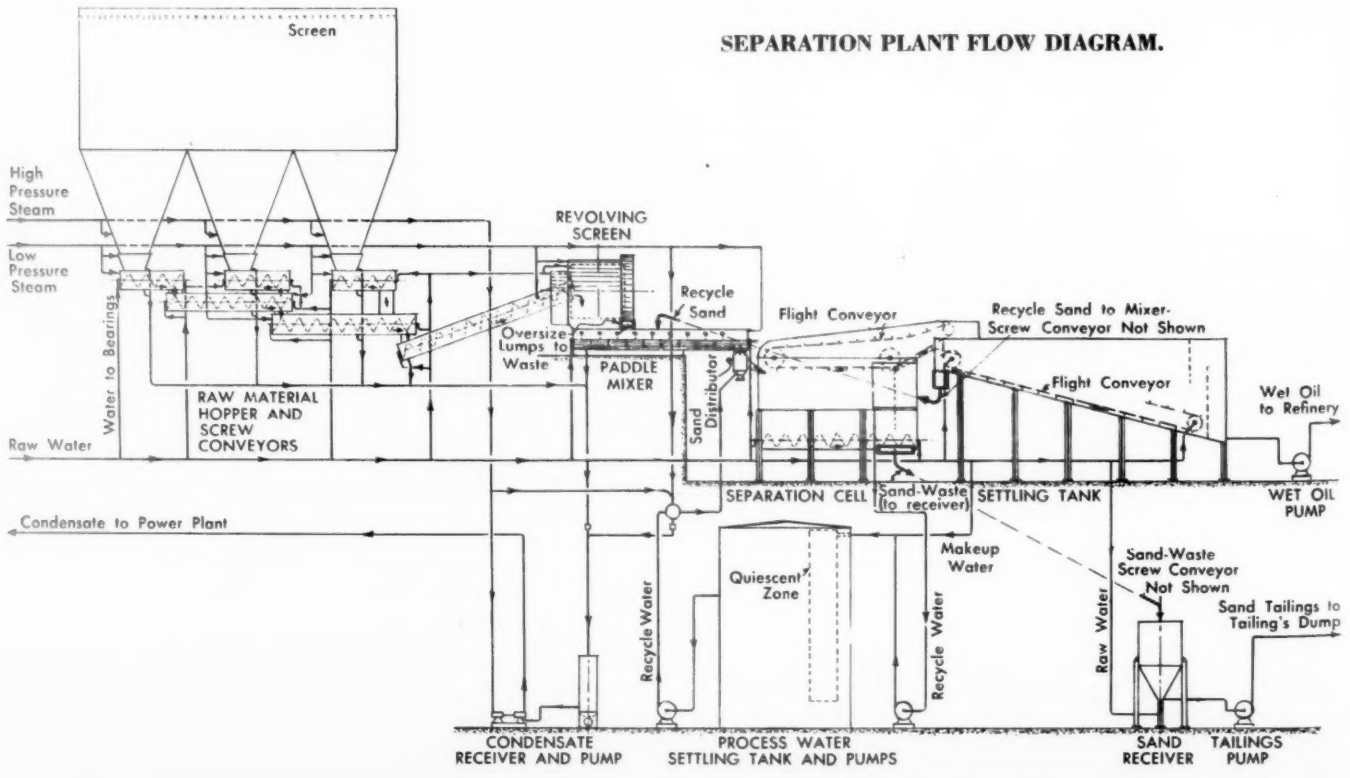
Close-up of dragline bucket excavating oil sand with temperature at —8 F. Sand was found to be soft and easily worked.

● **Mining.** For the present mining will be handled by a power shovel and dump trucks. The feasibility of this method has been amply demonstrated during construction when upwards of 15,000 cu yd were excavated and moved by the same means. Wear of the shovel teeth and bucket were not regarded as excessive and the trucks were able to discharge their loads easily. Experiments conducted during December, 1947, indicated that winter mining will not present insurmountable difficulties.

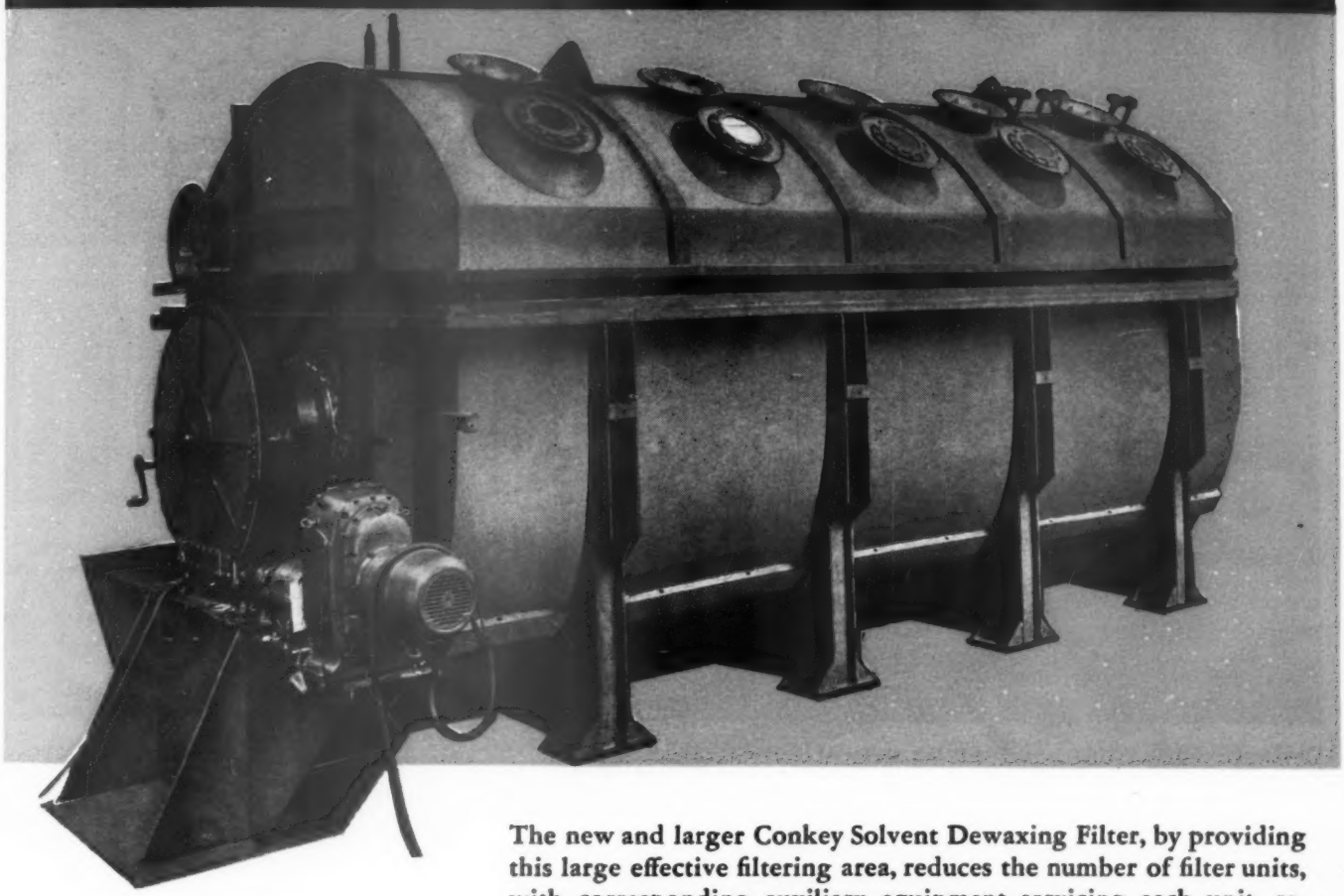
● **Separation unit.** The accompanying flow sheet will aid the reader in following the separation process. Trucks will discharge their loads directly into the raw material hopper from whence the oil sand is moved into the plant by a system of screw conveyors. The lower sections of the hopper are steam jacketed and equipped with steam and water jets to condition the sand for handling by the conveyors.

The oil sand enters the separation plant as a pulp and is screened to remove foreign objects before entering the mixer. The mixer is so designed that agitation is provided for about 15 min. During this period the oil film surrounding each

SEPARATION PLANT FLOW DIAGRAM.



625 SQUARE FEET OF NET EFFECTIVE FILTERING AREA IN A SINGLE UNIT



The new and larger Conkey Solvent Dewaxing Filter, by providing this large effective filtering area, reduces the number of filter units, with corresponding auxiliary equipment servicing each unit, required by large capacity modern M-E-K plants.

Briefly the advantages of this new Conkey Solvent Dewaxing Filter are:

- Lower installed cost
- More time on stream
- More throughput for equivalent filter area
- Lower operating costs
- Less maintenance

A General American engineer will be glad to give you more detailed information on the design and operation of large units.

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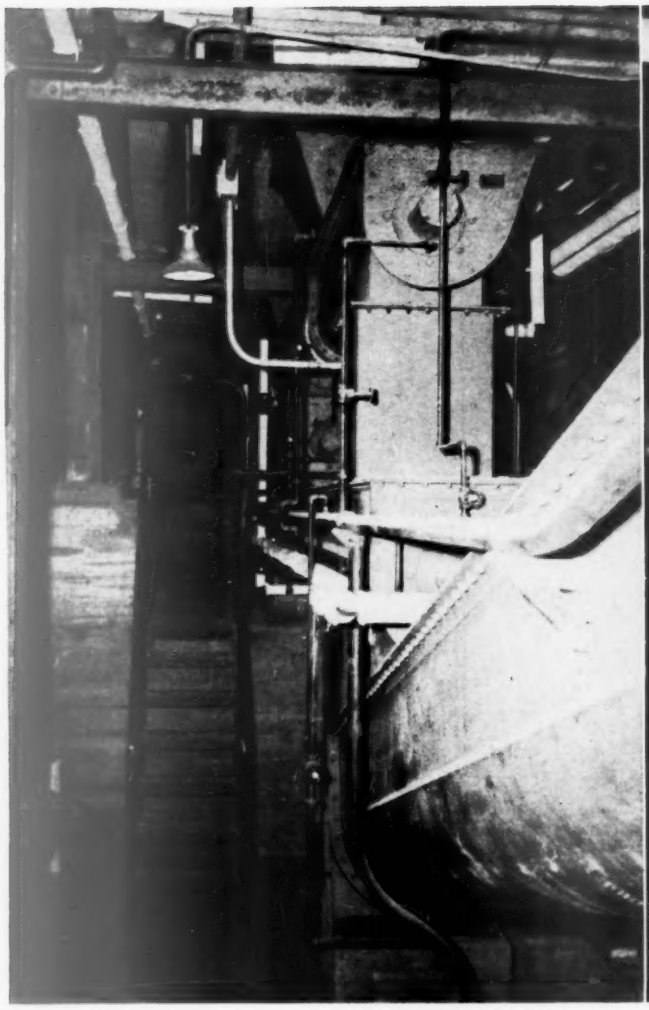
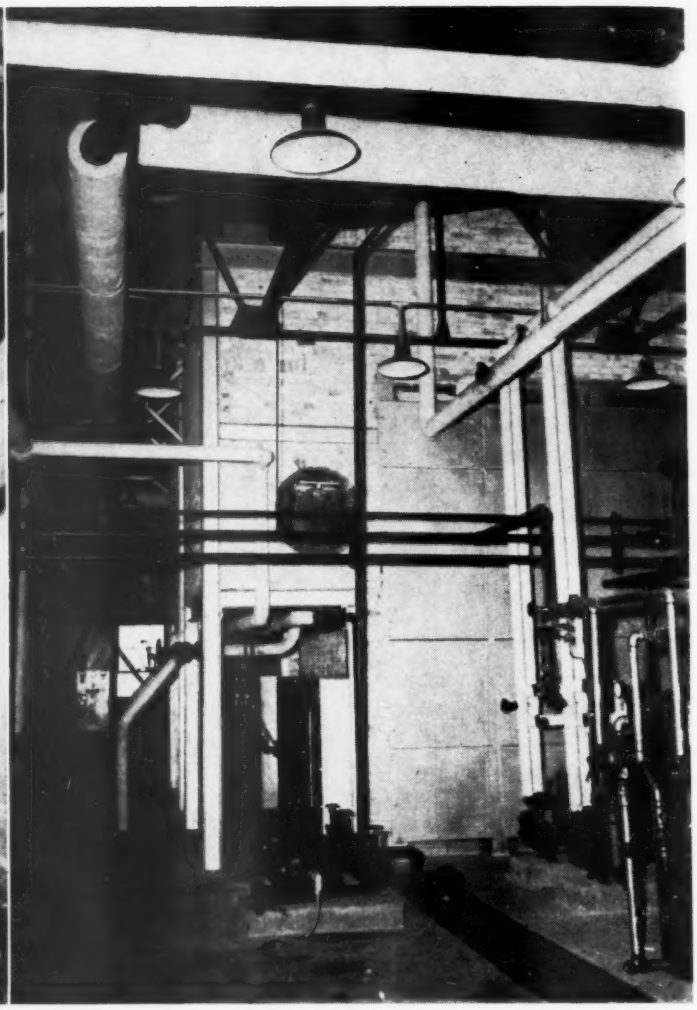


Feed and collecting conveyors under raw material hopper.



Interior power house.

grain of sand is scrubbed off and the oil particles so formed coagulated.

Aeration also takes place so that an oil froth, sand, and water are discharged through the sand distributor, into the separation cell. Air can also be added at the sand distributor in controlled amounts. Aeration by entrainment of air during mixing is desirable but not always possible and must sometimes be supplemented by the addition of compressed air. However accomplished, absolute overall control of the aeration step is essential because successful flotation in the separation cell depends upon it. In the separation cell, where temperatures are controlled by the addition of heated process water, the separated oil floats as a froth and is drawn off over a launder into the settling tank. Here final deposition of mineral matter takes place. These settlings carry down oil with them and consequently must be recycled to prevent waste.

Sand tailings are removed from the separation cell by means of a screw conveyor that elevates the sand to a point above the liquid level in the cell before depositing them in the sand receiver. After dilution with water the tailings are picked up from the sand receiver by a sand pump and discharged onto the tailings dump.

Water is withdrawn from the separation cell continuously and settled to remove silt accumulations before being reheated and returned to the circuit. Withdrawal and recycling of process water is handled by two 500-gpm centrifugal pumps. Heating is provided by exhaust steam in tubular exchangers.

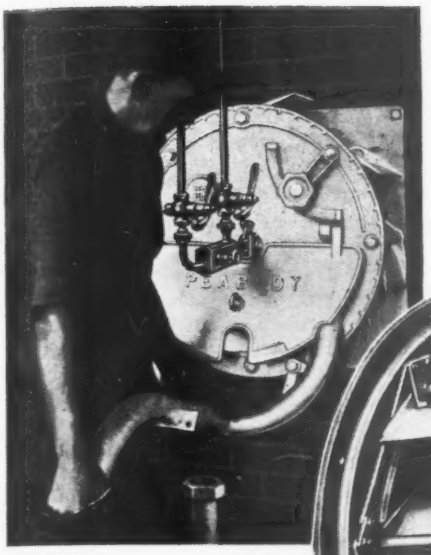
Independent variable motorized reducers are being used on all drives so that the operating speed of any unit may be changed relative to the others. This feature will permit a very complete study of operating conditions.

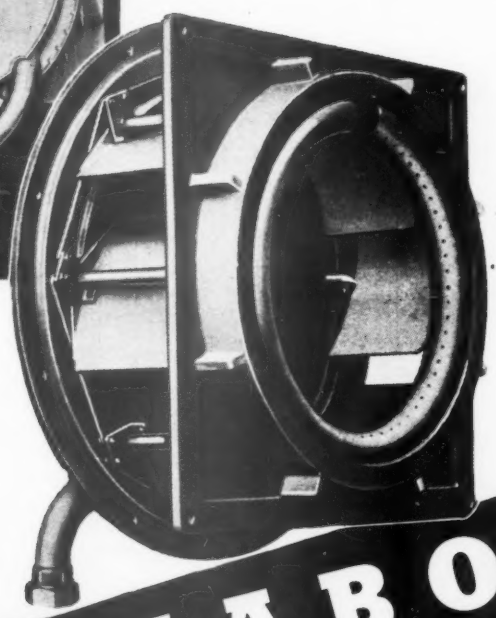
Much thought has been given to the selection of such items as journals and bearings. Here the previous operating experience of Oil Sands Limited has been of invaluable assistance. All bearings are water lubricated and pressure sealed by water against the entrance of abrasive material.

The separated oil leaving the settling tank is of approximately 10-deg API gravity, viscous, and will contain at times as high as 30 per cent water. To facilitate handling and to promote settling of the water the oil-water mixture is diluted with a 550 F EP distillate in the ratio of one part distillate to two parts oil on a dry basis. Dilution will be controlled by a ratio flow controller. The oil - water - distillate mixture is heated slightly and allowed to settle in a modification of a Denver Hydro-classifier, which eliminates approximately 65 per cent of the entrained water. The remaining water presents a problem in that it appears to be impossible to remove by standard methods. Although further plant scale pressure settling experiments are planned, it is felt that flash vaporization is most satisfactory. For this purpose a small Born-Upflo heater has been provided in which the oil-water-distillate mixture will be raised to 350 F and then flashed into an 18 ft flash drum. Pilot plant work indicates that this operation proceeds smoothly without foaming or excessive temperature fluctuations. It is expected that when the refinery is in operation enough heat can be picked up by heat exchange to make the use of the heater unnecessary.

● **Refining.** Despite the fact that separation costs are still in doubt, a tremendous amount of work has been done on the processing of the crude.

Research and development organiza-





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HEAVY DUTY GAS AND OIL BURNER

Burns either fuel alone or both simultaneously

Gas enters the furnace throat from a ring that is quickly replaceable while oil is being burned, if the gas ports become clogged. Center fired gas burners are also available.

For firing with oil, all Peabody Oil Atomizers, steam or mechanical, may be used.

The air register is designed to provide adequate control over flame characteristics and furnace conditions, with either natural draft or forced draft.

Heavy construction withstands damage and assures long life.

Simplified design makes installation easy and provides a strong wall and burner assembly.

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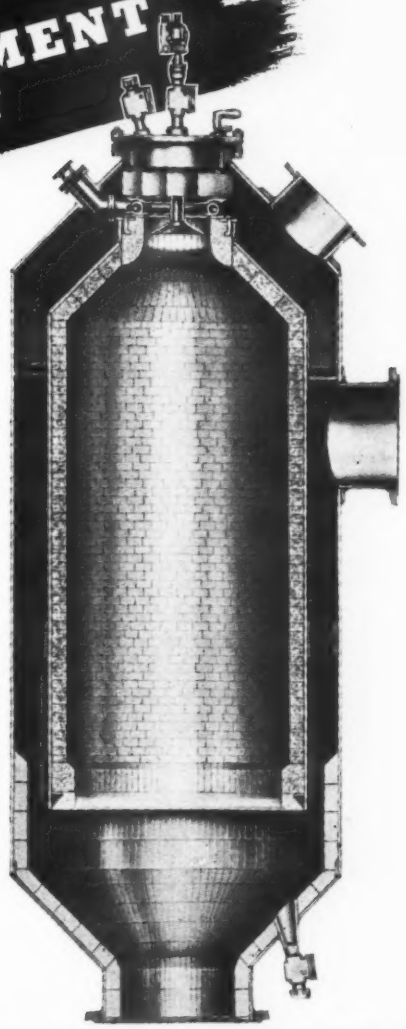

Direct Fired High Pressure Air Heaters

They are built for any working pressure and air delivery temperature.

The burner is a Peabody Combined Type, firing gas and oil. In the event of fuel failure, the burner can be quickly re-ignited while the furnace is under pressure.

Peabody Air Heaters are furnished as complete units, comprising the furnace, burner and all required controls. They are in service in synthetic rubber and high octane gasoline plants, also with gas turbines to reheat waste gases.

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tions both in Canada and the United States have demonstrated conclusively that the separated oil presents no difficulties to modern refinery techniques and further that a full line of high grade products can be produced on a very profitable basis. Briefly, the results of these studies reveal that continuous coking of the crude gives the following approximate yields:

Liquid	75 per cent
Coke	20 per cent
Uncondensable gas	5 percent

The liquid overhead can be separated into distillate and gas oil fractions. Catalytic reforming of the distillate yields a high octane, low sulphur gasoline, as does catalytic cracking of the gas oil. Polymerization of the available gas is of course recommended. No operations are involved that are not in every day use and on which ample operating experience is not available.

In view of the foregoing refining is not considered a problem with which the project has to deal and consequently the refinery is relatively simple and its chief functions will be the recovery of the diluent added and the supplying of the fuel necessary for heating, power generation, etc.

The crude obtained from oil sands is unique in its susceptibility to heat treatment. Thermal decomposition is quite marked at temperatures of 500 F and lower. Because of this characteristic it is virtually impossible to subject the crude to any ordinary refining operation without some cracking taking place, and consequently, although the refining unit is basically a simple topping unit, certain features have had to be provided that will permit control of the violent decomposition.

The heater is of the end-fired Born-Upflo type, and is equipped with 2-in. OD chrome-moly tubes and 1500 lb headers. By means of heat exchange the incoming charge will be raised to approximately 500 F and the heater outlet will be carried at 750 F. At this temperature considerable decomposition takes place with coke formation but it is felt that the high proportion of distillate in the charge will increase velocities to a point where coke deposition in the heater will provide little, if any, problem.

Back pressure on the heater will be controlled by an automatic back-pressure regulator. The discharge from the heater is transferred to a flash tower from the bottom of which a heavy residual fuel oil will be taken. Overhead from the flash tower will go directly to a 16-plate fractionator, the products of which will be gasoline, distillate, diesel fuel, and an 18 to 20-deg API furnace oil. Fin-tube exchangers have been used exclusively in the installation both for condensing and heat recovery.

● **Power house.** Steam, both for process heating and power, will be supplied by two 6000 lb per hr double-drum water-tube boilers operating at 175 psi. These units are oil-fired and have air-cooled floors and walls, which permit high operating rates.

Power will be generated by a turbo-generator unit and a diesel-driven unit will provide power for peak loads and during shut downs, etc. Switching equipment permits the control of electrical power to any section of the plant and adjoining camp.

The power house also contains filtration and chlorination equipment for water treatment; fuel oil supply tanks, pumps, and heater; feed-water heater, exhaust steam accumulator, compressors, etc.

● **Water supply.** Water will be drawn directly from the Athabaska River by means of a seven-stage vertical pump suspended in a 6-ft well 35 ft deep. Intake pipes project horizontally from the bottom of the well into the river channel.

A surge tank has been provided on the main water line to the plant in which the level will be automatically maintained. A 600-gpm reciprocating pump taking suction on this tank goes into operation when line pressure drops below 35 psi. This same pump can be used to boost line pressure in the event of fire.

● **Special features.** The considerable amount of process steam required will be obtained chiefly from the turbo-generator, which exhausts against an 8 psi back pressure.

This low pressure steam, together with that from all other steam-driven equipment throughout the plant, is collected in a single system and will be used for heating process water, buildings, etc.

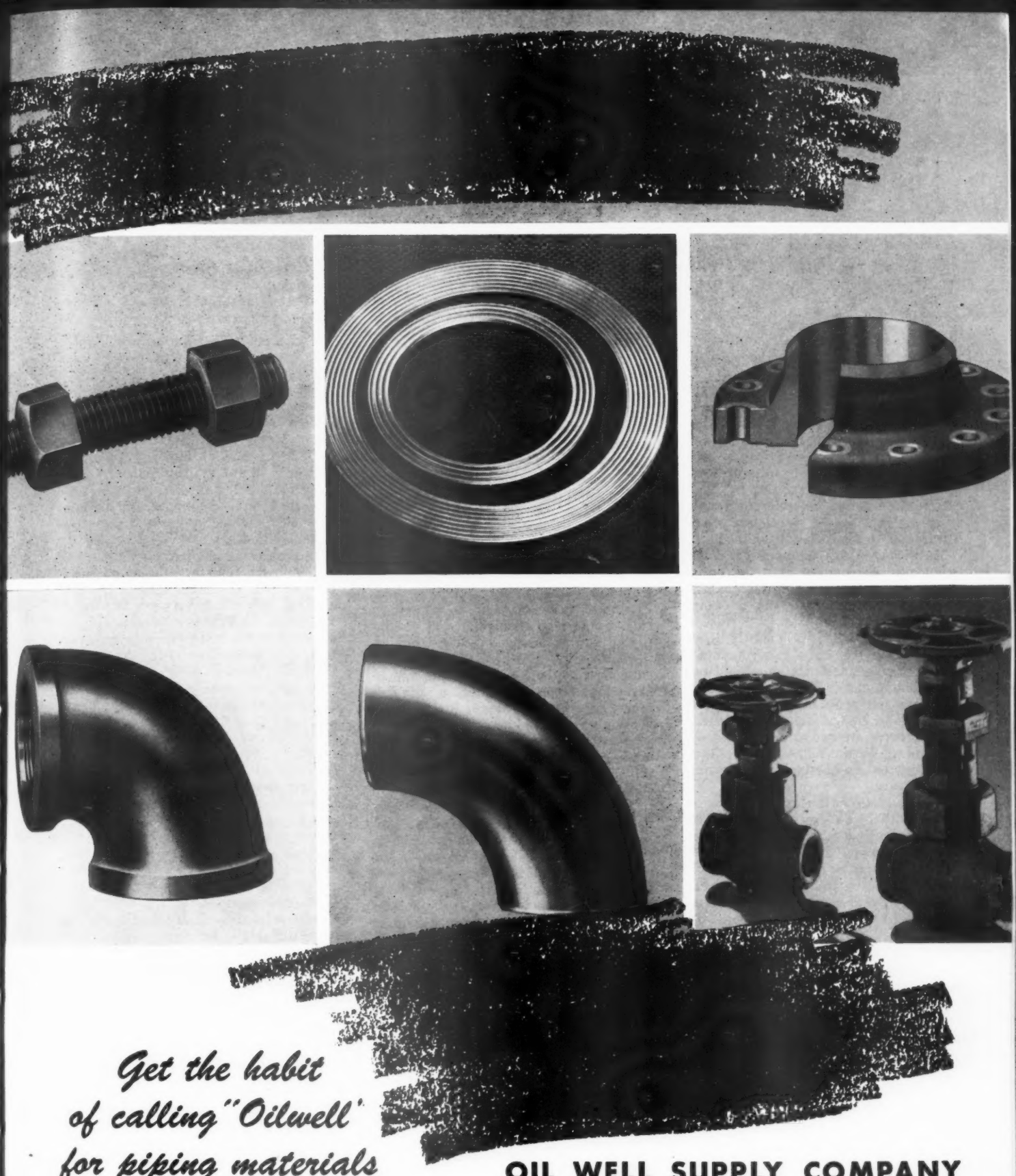
All condensate from steam jackets, water heaters, radiators, etc., will be returned to the power house and it is expected that boiler make-up will be very low with a proportionate reduction in feed-water treating problems.

Because of the basic purpose of the plant, numerous sampling devices have been provided on all process equipment from which to take material for detailed study of every step. For the same reason generous use has been made of instruments for the measurement and recording of pressure, temperature, and flow rates.

● **Conclusion.** Test runs are scheduled to begin in June of this year and satisfactory results would make deposits containing several billion barrels of oil available for economic development. It should be mentioned, however, that there are still larger quantities of oil under heavy overburden that could not be obtained by the methods outlined. These deposits, too, are receiving attention and at the present time the Alberta Research Council is studying several *in situ* methods of recovery. Although it is too early to report on the details of their experiments, it can be said that work done to date has produced encouraging results.

The Born Engineering Company of Tulsa and Canadian Brown Steel Tank Company of Brandon, Manitoba, are general contractors. The author represents both the Alberta Government and the contractors.

N.B. For more detailed data readers are referred to various publications by Dr. K. A. Clark of the Alberta Research Council, Edmonton. ★★★



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Hydrocarbon absorption and fractionation process design methods

Part 12. Preliminary Steps in Multi-component Calculations

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THERE are several multicomponent fractionation calculation methods worthy of consideration. Although they are all based on the theoretical equilibrium plate concept and use component material balances along with the phase equilibrium relationship, the calculation procedures differ. These differences are due to different starting points, to different simplifying assumptions, or to characteristic features of the calculation methods.

EXCLUSIVE

Multicomponent fractionation calculations are so complex that the entire pattern of the method is affected by starting point, simplifying assumptions, etc.

It is not possible to classify these methods definitely but a fairly accurate and descriptive classification would be: (a) Plate-to-plate, (b) short-cut, (c) empirical, (d) graphical, and (e) overall equations. Under each of these classifications there are two or more methods, each known by the name of the author that presented the method in the technical literature.

Plate-to-plate calculations may be started with given desired products to find the required number of theoretical plates and reflux or the plate-to-plate calculations may be started with a given number of plates and reflux to find the composition of the terminal products as the objectives of the calculations. In either procedure, trial and error calculations are involved.

All other methods than the plate-to-plate methods were proposed as short cuts to the plate-to-plate methods. In this and following installments, the various multicomponent fractionation calculation methods will be described and illustrated so the reader will be able to compare and use them.

COMPARISON OF BINARY AND MULTICOMPONENT DISTILLATION

There are certain similarities and differences between the binary and multicomponent fractional distillation and the calculation methods for these processes.

In general, the same type of equipment is used for both processes. The drawing given as Fig. 39 in Part 10 represents a fractionating column that may be used in binary or multicomponent distillation.

The functions of the different parts of the column are the same for binary and multicomponent applications. In the *enriching* section, the higher boiling components are removed from the vapors going up the column to produce the desired distillate product. In the *stripping* section, the lower boiling components are removed from the liquid going down the column to give the desired bottoms product.

Heat must be supplied to the plates in the stripping section and removed from the plates in the enriching section. The most practical, but not the most efficient thermodynamically, way of supplying and removing these heat quantities is by a reboiler at the bottom and a condenser at the top. The rising vapors carry heat from the reboiler up the column and the reflux liquid provides the cooling on each plate. Only one sharp separation between adjacent components can be made in one column, and this requires efficient enriching and stripping sections.

The composition of the desired distillate determines a relationship between the pressure and temperature at the top of the column. Likewise, the composition of the bottoms product determines a relationship between the pressure and temperature at the bottom of the column. The pressure drop is small so the difference between the boiling point of the bottoms and the dew point of the distillate gives the temperature gradient at any pressure.

With these pressure-temperature relationships, the operating pressure can be established by fixing either the top or bottom temperature. The top temperature may be established by the cooling water temperature, while the bottom temperature may be established by the temperature of the heating medium available. A higher pressure requires a higher level heat while permitting the use of warmer cooling water. Thus, the design of both binary and multicomponent fractionators involves setting operating conditions from: (a) Product compositions, (b) cooling water temperature, and (c) temperature of heating fluid (or steam pressure).

For any separation of a complex mixture, there is a minimum reflux (at infinite plates) and a minimum plates (at total reflux) relationship. These limiting conditions are much more difficult to estimate for multicomponent mixtures than for binary systems.

Component distribution calculations are made by the combination of component *material balance* and liquid-vapor *equilibrium* calculations plus *heat balances* for both binary and multicomponent fractionation. The latter is much more complex because the additional components make it impossible to define the vapor-liquid equilibrium in terms of x, y and the relative volatility in a simple form that can be combined with material balance relationships for a straight forward solution.

In multicomponent fractionators, like in binary fractionators, the molal downflow in each section is almost constant and the difference between the liquid and vapor equals the quantity of the terminal product. In the enriching section, the up-flowing vapors are greater than the down-flowing liquid by the amount of the distillate. Likewise, in the stripping section the down-flowing liquid is greater than the up-flowing vapors by the amount of the bottoms product. The enriching section vapor will be greater than the stripping section vapor by the amount of vapor from flashing the feed. Likewise, the stripping section liquid will be greater than the enriching section liquid by the amount of liquid from flashing the feed. The feed is usually between its boiling and dew points.

From the above discussion, it is clear that multicomponent distillation is closely related to binary distillation but more difficult to calculate. This is particularly true in the case of three distributed components where the one of intermediate volatility appears in both products in appreciable quantities giving at least three components that appear in both distillate and bottoms.

PLATE-TO-PLATE CALCULATIONS

In the discussion of two-component distillation, given in Parts 10 and 11, the McCabe-Thiele graphical XY diagram method was referred to as a classic because it gives a rigorous yet rapid and clear solution of binary fractionation problems. There is no similar method for multicomponent calculations. It is almost impossible to have these three qualities, namely: Rigorousness, rapidity, and visual clarity, in any one multicomponent fractionation design method.

Plate-to-plate calculations are rather widely recognized as the standard for comparing results by other multicomponent methods. Two plate-to-plate calculation procedures may be used, depending upon the starting point and the objective of the calculations. These

plate-to-plate calculation procedures are known as the Lewis-Matheson and the Thiele-Geddes methods.

Starting with the desired products, the Lewis-Matheson procedure has as its objective the number of equilibrium stages for the fractionator. Starting with the number of plates, the Thiele-Geddes method has as its objective the compositions and yields of the products.

In both of these methods, there are two unknowns that must be found by trial. These are the reflux ratio and the plate temperatures, which may be considered primary and secondary variables, respectively, to be found by trial and error or successive approximations by methods outlined later. In either procedure and at any assumed reflux ratio, trial and error calculation, which is an equilibrium flash vaporization such as those illustrated in Part 4, is more complex and time consuming than two-component equilibrium calculations.

This difference in the equilibrium flash vaporization calculations for binary and multicomponent systems makes multicomponent fractionation calculations much more complex than similar calculations for binary systems. For two components, specifying the mol fraction of either component in either phase is sufficient to fix the other mol fractions as well as the temperature. As was shown in the Part 4 examples, this is not possible for three or more components. These trial and error equilibrium calculations must be made on each stage in going through the column. All equilibrium and material balances must be balanced out for each assumed reflux ratio before the optimum reflux ratio may be selected.

Relative volatilities may be used in multicomponent plate-to-plate calculations in a similar way they were used in the binary calculations given in Table 54 of Part 11. This procedure will be illustrated later.

Fig. 51 shows a McCabe-Thiele X Y diagram for a binary mixture and also a concentration diagram illustrating the method proposed by Lewis-Matheson for matching or meshing the concentrations in both stripping and enriching sections. The temperature gradient is also shown on this plot.

The two diagrams on Fig. 51 may be considered to represent the salient features of binary and multicomponent distillation calculations. As noted in Fig. 51, the basic principles are the same, namely, step-wise calculations by phase equilibria and component material balance relationships.

The equilibrium expressions with no subscripts apply to both binary and multicomponent systems, whereas those with the G and H subscripts are for binary systems only. The component material balance, or operating line, equations apply to both binary and multicomponent systems.

PRELIMINARY STEPS

Before taking up the various multicomponent calculation procedures, the preliminary steps common to all methods will be discussed. These preliminary steps are:

Step 1. Make component material bal-

FIG. 51. Summary of fractionation fundamentals as illustrated by: (a) an XY diagram for binary mixtures and (b) a composition plot for multicomponent mixtures.

SUMMARY OF FRACTIONATION FUNDAMENTALS

Basic principles of fractional distillation are the same for binary and multicomponent systems, namely: step-wise calculations by phase equilibria and component material balance relationships.

Equilibrium

$$K = \frac{Y}{X} \text{ or } \frac{KV}{L} = \frac{v}{l} \quad \text{or} \quad X_G = \frac{1 - K_H}{K_G - K_H} \text{ and } Y_G = K_G X_G$$

where G and H = components of binary system.

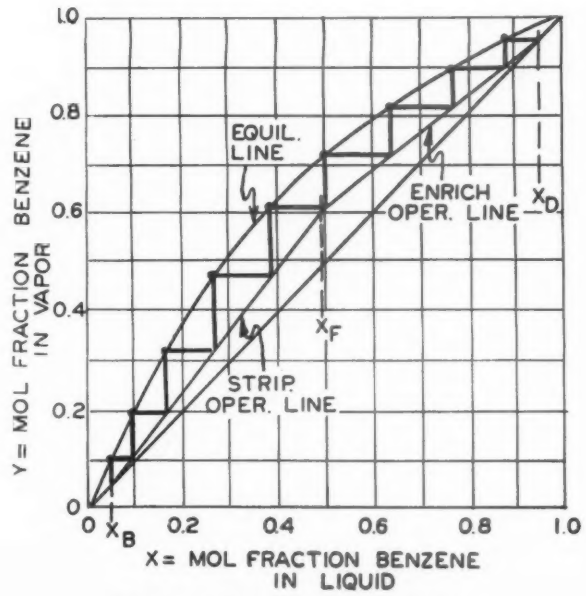
Component material balances—operating lines—Haus-brand equations.

$$\text{Enriching section } y_i = \frac{L_{i-1}}{V_i} x_{i-1} + \frac{D}{V_i} x_d$$

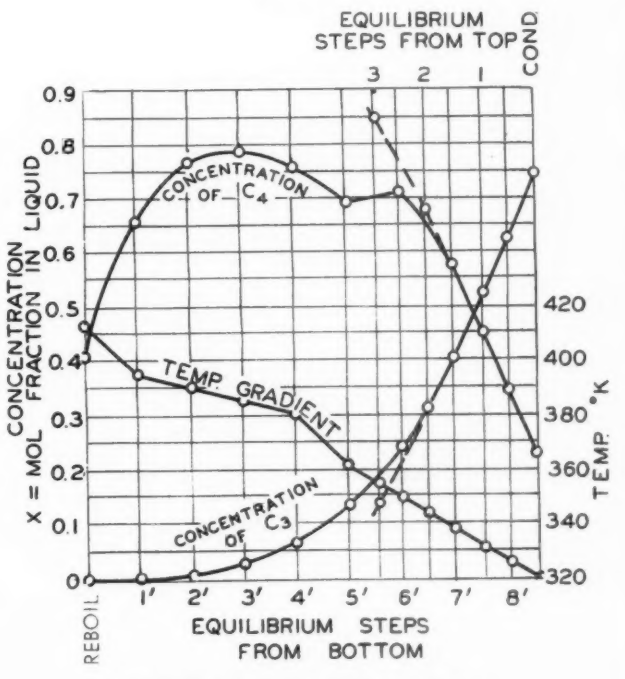
i = any plate numbered from top.

$$\text{Stripping section } y_j = \frac{L_{j+1}}{V_j} x_{j+1} + \frac{B}{V_j} x_b$$

j = any plate numbered from bottom.



McCABE-THIELE DIAGRAM FOR BINARY MIXTURE



LEWIS-MATHESON PLOT FOR MULTICOMPONENT MIXTURE

SUMMARY OF PRELIMINARY STEPS IN MULTICOMPONENT FRACTIONATION CALCULATIONS

1. Component material balance for desired separation, using relative volatilities to estimate component distribution.

2. Equilibrium flash vaporization of feed at T and P conditions.

3. Reflux temperature, composition and quantity (from assumed reflux ratio).

4. Top tray temperature and induced reflux quantity and composition.

5. Reboiler temperature, vapor composition and quantity (from reflux and feed condition by heat and material balances).

6. Bottom tray temperature and reboiled vapor quantity and composition.

7. Heat balances to obtain duties of reflux condenser and reboiler and to check L and V quantities at various points in the tower (not shown here).

All methods of making theoretical plate and component calculations require these preliminaries.

NOTE: All quantities are given in mols/hour.

MATERIAL BALANCE

	Feed	Distillate	Bottom
C_1	26	26.0	
C_2	9	9.0	
C_3	25	24.6	0.4
C_4	17	0.3	16.7
C_5	11		11.0
C_6	12		12.0
	100	59.9	40.1

FLASH ON FEED

Assume V/L = 2.0

	$K_{300\#}^{175°F.}$	1+VK/L	$l_f = \frac{f}{1+\frac{VK}{L}}$	$v_f = f - l_f$
C_1	13.0	27.0	1	25
C_2	3.2	7.4	1	8
C_3	1.3	3.6	7	18
C_4	0.63	2.26	8	9
C_5	0.27	1.54	7	4
C_6	0.13	1.26	10	2
			34	66

$\frac{V}{L} = \frac{66}{34} =$ 1.95 vs 2.0 check

REFLUX AND TOP TRAY

Reflux, $L_d = 1.5 \times 59.9 = 90$

	$K_{300\#}^{63°}$	d/K	l_d	v_1	$K_{300\#}^{105°}$	v_1/K
C_1	7.7	3.4	5.1	31.1	9.8	3.2
C_2	1.5	6.0	9.1	18.1	2.05	8.8
C_3	0.5	48.2	73.0	97.6	0.76	128.0
C_4	0.16	1.9	2.8	3.1	0.30	10.3
		59.5	90.0	149.9		150.3

REBOILER AND BOTTOM TRAY

$V_b = 90 + 34 = 124$

	$K_{300\#}^{300°}$	bK	v_b	l_1	$K_{300\#}^{280°}$	l_1/K
C_3	2.7	1.1	2.3	2.7	2.4	6.5
C_4	1.45	24.2	50.5	67.2	1.3	87.4
C_5	0.82	9.0	18.8	29.8	0.72	21.4
C_6	0.49	5.9	12.3	24.3	0.40	9.7
		40.2	83.9	124.0		125.0

TABLE 55. Summary of preliminary steps in multicomponent fractionation calculations.

MAKE COMP. MAT. BAL-

ance to divide the change into distillate and bottoms products of compositions satisfying the desired separation but only approximating the final compositions that will be found by completing the design.

Step 2. Make an equilibrium flash vaporization calculation on the feed to obtain the quantities of vapor and liquid to be added to the corresponding streams in the column.

Step 3. Assume a liquid reflux ratio for the enriching section, or, alternately, assume a vapor boil-up ratio in the stripping section, depending upon the separation requirements. This assumption is made from experience. More than one trial is frequently necessary to establish the reflux ratio.

Step 4. Make dew point calculations on the distillate to fix pressure, assuming top temperature is set by cooling water temperature, and find the composition of the reflux as the equilibrium (dew point) liquid.

Step 5. Find temperature of the top tray as the dew point of the total tower overhead, i.e., distillate plus reflux, the reflux being established already, and obtaining the composition of the liquid leaving the top tray as a by-product of this temperature estimation.

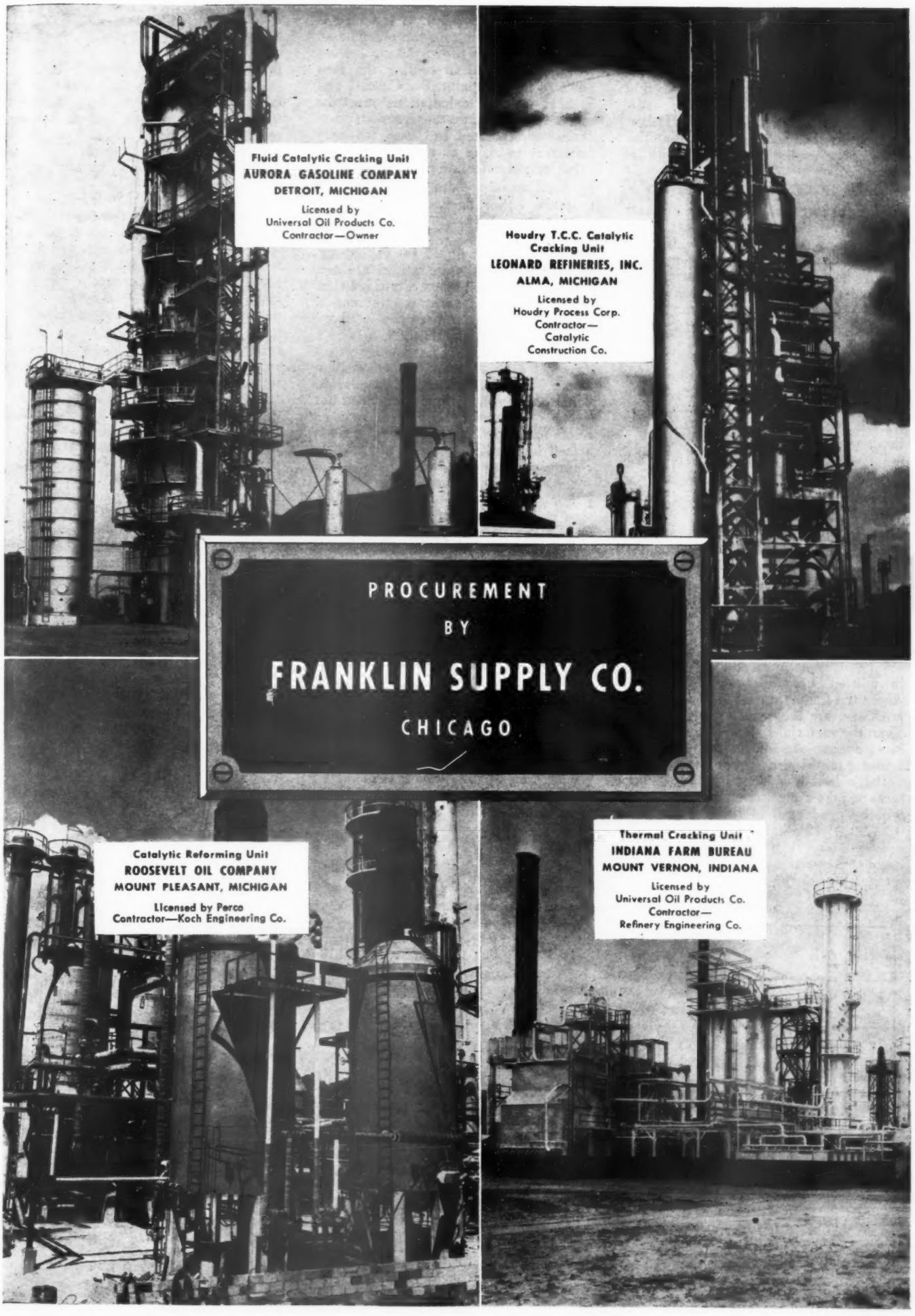
Step 6. Make bubble point calculations on the bottoms product to fix bottom temperature, assuming tower pressure has already been established by previous calculations, and find the composition of the boiled-up vapors as the equilibrium (bubble point) vapor.

Step 7. Estimate and check the boil-up quantity. This may be done by assuming constant molal overflow, which permits calculating liquid and vapor quantities from the similar quantities in the enriching section plus the vapor and liquid from flashing the feed. As an alternate and a check on this estimate, a heat balance could be made to find the quantity of vapor necessary to deliver the required heat load.

Step 8. With the known amount and composition of the reboiler vapors, the liquid leaving the bottom tray is readily computed and the bottom tray temperature may be found. The composition of the vapors leaving the bottom tray are also calculated.

In Table 55, the calculations outlined in the above eight steps are illustrated for a six component mixture. It will be noted that the feed flashed to give two-third vapor and one-third liquid. The composition and quantity of the liquid leaving the top tray may be found by multiplying each v_1/K number by (90/150.3). Likewise, the vapor leaving the bottom tray may be found by multiplying each l_1/K number by (83/124).

It will be noted that the calculations given in Table 55 are made in terms of component molal quantities rather than mol fractions. Multicomponent fractionation calculations could be made in terms of mol fractions of the various components but this would be confusing because each composition must be figured in terms of the total liquid or vapor at each plate. A great deal of time is saved by using the mols of each component throughout. Small letters (v, l, d, b, and f) are used to designate mols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Cracking Unit
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of a given component in the vapor, liquid, distillate, bottoms or feed.

In some cases, it is necessary to know the feed plate temperatures and compositions. Some calculations use this information directly and some indirectly. In the next section, the feed plate will be studied and following that the remaining "preliminary steps" will be continued.

FEED PLATE RELATIONSHIPS

The juncture of the enriching and stripping sections is the logical point for introducing the feed, provided the feed is at or between its boiling and dew points. The feed is usually introduced at a point where the composition of the liquid (or vapor) in the column is the same as the feed, regardless of its temperature and phase conditions.

There are five possible feed conditions, as shown in Table 56, where the material balance relationships at the feed plate are given. In this table V_{n+1} is the vapor to the enriching section and V_m is the vapor from the stripping section. The liquid to the stripping section is L_{m+1}, while the liquid from the enriching section is L_n. The vapor and liquid portions of the feed are identified by V_f and L_f. For convenience, it may be assumed that the basis for Table 56, which shows five feed relationships, is the introduction of the feed at a point where its composition is the same as the vapor or liquid in the tower.

For Cases 2, 3, and 4, for which the feed is at or between its boiling and dew points, it is assumed that the feed is introduced into the tower at a point where the temperatures, as well as compositions, are the same as for the feed. Then the material balance relationships involve simple addition of vapor and liquid quantities, as shown.

If the feed is below its boiling point, some vapors from the stripping section will be condensed in heating the feed up to the boiling point. If the feed is above its dew point, on the other hand, some liquid from the enriching section will be vaporized in cooling the feed down to its dew point. For Cases 1 and 5, heat balance calculations must be made to determine the fractions condensed or vaporized. In Case 3, it is only necessary to make an equilibrium flash vaporization calculation to find V_f and L_f. For Cases 2 and 4, it is not necessary to make either flash or heat balance calculations.

For Cases 1 and 5, the compositions of feed and tower liquid (or vapor) are the same but the temperatures are not. In Case 1, the feed temperature is below the feed plate temperature, whereas in Case 5 the feed temperature is above the feed plate temperature.

Although the feed is usually introduced at a point where its composition matches the composition of the liquid (or vapor) in the column, this need not be the situation for the material balance relationships in Table 56 to hold. Such a feed location would alter the equilibrium compositions, however, so it is not considered good practice.

For many of the multicomponent design methods, an essential preliminary step is the estimation of the feed plate temperature and in some of these it is necessary to have the compositions at the feed plate. These conditions may be estimated from a consideration of the "pinch points" or points of constant composition that exist immediately above and below the feed plate.

If plate-to-plate calculations are started at the top of a fractionator with a given distillate composition and reflux ratio, a point will be reached several plates down the enriching section where the compositions of all components are constant and do not change with further calculations for more theoretical plates. The temperature for this zone of constant composition is also constant and is called the "upper pinch point temperature". At this temperature, the least volatile component in the distillate has reached its maximum concentration.

Likewise, plate-to-plate calculations may be started at the bottom of the stripping section with a given bottoms product composition and assumed boil-up ratio. In working up the column plate by plate, a point will be reached where the compositions of all components are constant and do not change with further calculations for more theoretical plates. The temperature for this zone of constant composition is also constant and is called the "lower pinch point temperature". At this temperature, the most volatile component in the bottoms product has reached its maximum value.

As the pinch point locations, temperatures and compositions depend upon the reflux ratio assumed, the computation of upper and lower pinch point temperatures is a means of checking the adequacy of an assumed reflux ratio. The reflux ratio must be high enough to bring the upper and lower pinch temperatures reasonably close together, but not equal or overlapping. In other words, the enriching section pinch point temperature must be lower than the stripping section pinch point temperature.

Jenny[17] points out that there is a maximum feed plate temperature that corresponds to an infinite number of theoretical plates in the enriching section, and that there is a minimum feed plate temperature that corresponds to an infinite number of plates in the stripping section.

The temperatures of the feed plate and the plate above the feed plate can be estimated by using the pinch point phenomena. This estimate involves making an assumption of the difference between the feed plate temperature and the pinch point temperature, and then checking this assumption. This calculation is simple, as will be shown by an

TABLE 56. Vapor-liquid feed plate material balance relationships for different feed conditions. These feed plate relationships apply to binary and multicomponent mixtures.

FEED PLATE RELATIONSHIPS				
Case	Phase and temperature of feed	Vapor to enriching section	Liquid to stripping section	Remarks
1	Liquid below boiling point	$V_{n+1} = (1 - w)\ V_m$	$L_{m+1} = L_n + F + wV_m$	w = fraction of V_m condensed by subcooled feed
2	Liquid at boiling point	$V_{n+1} = V_m$	$L_{m+1} = L_n + F$	$F = L_f$
3	Liquid-vapor between boiling and dew points	$V_{n+1} = V_m + V_f$	$L_{m+1} = L_n + L_f$	$F = V_f + L_f$
4	Vapor at dew point	$V_{n+1} = V_m + F$	$L_{m+1} = L_n$	$F = V_f$
5	Vapor above dew point	$V_{n+1} = V_m + F + zL_n$	$L_{m+1} = (1 - z)\ L_n$	z = fraction of L_n vaporized by superheated feed

example. The relationships for estimating the pinch points are developed below.

In the enriching section, the liquid leaving any plate is l_i and the vapor rising to this plate from the plate below is v_{i+1}.

A material balance around the top part of the column, including the condenser and the i^{th} plate gives:

$$v_{i+1} = l_i + d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (92)$$

For the heaviest components of the distillate, $v_{i+1} = v_i$ and $l_i = l_{i-1}$ at the zone of maximum concentration giving:

$$v = l + d \quad . \quad . \quad . \quad . \quad . \quad (92A)$$

By equation (81 (Part 10):

$$\frac{v}{l} = \frac{KV}{L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (81)$$

Combining equations (81) and (92A) gives:

$$\frac{KV}{L} = 1 + \frac{d}{l} \quad . \quad . \quad . \quad . \quad . \quad (93)$$

Equation (93) may be rearranged to give:

$$\frac{l}{d}\left[\frac{KV}{L} - 1\right] = 1 \quad . \quad . \quad . \quad (94)$$

$$l = \frac{d}{\left[\frac{KV}{L} - 1\right]} \quad . \quad . \quad . \quad . \quad (95)$$

Equations (94) and (95) may be applied to all components in the distillate. When d approaches zero as is the case for the heaviest components in the distillate, KV/L approaches unity and:

$$K = L/V \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (96)$$

Equation (96) is applied to the least volatile component appearing in the distillate.

In like manner, equations for the stripping section pinch point may be derived. In the stripping section, the vapor leaving any plate is v; and the liquid overflowing from the plate above is l_{j+1}. A material balance around the bottom part of the column, including the reboiler and the j^{th} plate gives:

$$l_{j+1} = x_j + b \quad . \quad . \quad . \quad . \quad . \quad . \quad (97)$$

For the lightest components of the bottoms product, $v_j = v_{j-1}$ and $l_{j+1} = l_j$ at the zone of maximum concentration, giving:

$$l = v + b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (97A)$$

Combining equations (81) and (97A):

$$\frac{L}{KV} = 1 + \frac{b}{v} \quad . \quad . \quad . \quad . \quad . \quad . \quad (98)$$

Equation (98) may be rearranged to give:

$$\frac{v}{b}\left[\frac{L}{KV} - 1\right] = 1 \quad . \quad . \quad . \quad (99)$$

$$v = \frac{b}{\left[\frac{L}{KV} - 1\right]} \quad . \quad . \quad . \quad . \quad (100)$$

Equations (99) and (100) may be applied to all components in the bottoms product. When b approaches zero as is the case for the lightest components in the bottoms product, L/KV approaches unity and:

TABLE 57. Feed plate calculations for Table 55 example. (Consolidation of Jenny[17] calculations.)

Enriching section

Temperature estimation: $\frac{L}{V} = \frac{90.0}{149.9} = 0.6$

K for n-C_4=0.6 at 170 F=enriching section pinch temperature.

Assume that temperature of plate above feed is 10 F lower or 160 F.

C_1 and C_2 in liquid from enriching section

	d	K 160 °F	VK/L	$\left[\frac{VK}{L} - 1\right]$	l_n Eq. (95)	$v_m = l_n + l_f$
C_1	26	12.5	20.8	19.8	1.31	2.31
C_2	9	2.95	4.92	3.92	2.30	3.30

C_3 and C_4 in vapor from stripping section

	v_m	K 205 F	v_m/K
C_1	2.31	15.0	0.20
C_2	3.30	3.8	0.90
C_3	C	1.55	0.65C
C_4	G	0.80	1.25G
C_5	3.80	0.38	10.0
C_6	1.76	0.19	9.3
	83.9		83.9

C=45.6 and G=27.1

Stripping section

Temperature estimation: $\frac{L}{V} = \frac{124.0}{83.9} = 1.48$

K for C_3=1.48 at 195 F=stripping section pinch temperature.

Assume that temperature of the feed plate is 10 F higher or 205 F.

C_5 and C_6 in vapor from stripping section

	b	K 205 F	L/KV	$\left[\frac{L}{KV} - 1\right]$	v_m Eq. (100)
C_5	11	0.38	3.90	2.90	3.80
C_6	12	0.19	7.80	6.80	1.76

Feed plate temperature check

	v_m	K 205 F	v_m/K	$l_{m+1} = v_m + b$
C_1	2.31	15.0	0.20	2.3
C_2	3.80	3.8	0.90	3.3
C_3	45.60	1.55	29.60	46.0
C_4	27.1	0.80	32.90	43.8
C_5	3.8	0.38	10.00	14.8
C_6	1.8	0.19	0.30	13.8
	83.9		83.90	124.0

Checks 205 F

Plate above feed temperature check

	l_E	K 160 F	l_nK	$v_{n+1} = l_n + d$
C_1	1.3	12.5	16.5	27.3
C_2	2.3	2.95	6.8	11.3
C_3	39.0	1.14	44.5	63.6
C_4	35.8	0.54	19.3	36.1
C_5	7.8	0.23	1.8	7.8
C_6	3.8	0.10	0.4	3.8
	90.0		89.3	149.9

$l_n = l_{m+1} - l_f$; checks 160 F

$$K = L/V \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (101)$$

Equation (101) is applied to the most volatile component in the bottoms.

Equations (94), (96), (99), and (101) are used in making feed plate calculations. The procedure will be outlined and illustrated below.

FEED PLATE CALCULATION PROCEDURE

Eight preliminary calculation steps common to all multicomponent fractionation design methods were listed earlier in this chapter. These eight steps are illustrated in Table 55. The next steps are concerned with the feed plate temperature and compositions.

Step 9. Estimate pinch point temperature in enriching section where compositions of all components are constant as the temperature at which the K value for the least volatile component of the distillate is equal to L/V in the enriching section.

Step 10. Estimate pinch point temperature in stripping section where compositions of all components are constant as the temperature at which the K value for the most volatile component of the bottoms product is equal to L/V in the stripping section.

Step 11. From these pinch point temperatures, assume temperatures for the feed plate and the plate above the feed.

Step 12. Using equation (95), estimate quantities of the nondistributed and most volatile components in the liquid from enriching section and add to these the quantities of same components in the liquid portion of feed to find amounts of these light components in the vapor from stripping section.

Step 13. Using equation (100), estimate the amounts of the nondistributed and heavy components in the vapor from the stripping section.

Step 14. Combining results by Steps 12 and 13 with component material balance, complete the calculation of the vapor from the stripping section.

Step 15. With the vapor found in Step 14, check the assumed feed plate temperature by making a dew point calculation.

Step 16. From the dew point liquid of Step 15 and the liquid fraction of the feed, find liquid from enriching section and check temperature of the bottom plate in the enriching section by a bubble point calculation.

EXAMPLE

The application of the equations and the procedure outlined above to the calculation of the feed plate temperature and compositions for the same example used in Table 55 is given in Table 57. This is the example used by Jenny[17] in illustrating these calculations. The same numbers are used here with some rearranging and revisions.

In estimating the temperatures, 170 F and 195 F are found as the upper and lower pinch points corresponding to the prevailing L/V ratios by the computations shown in the upper part of Table 57. The difference between these temperatures is 25 F. This is not necessarily the difference between the temperatures of the feed plate and the plate above. The 170 F and 195 F pinch temperatures do help locate these tower temperatures, however.

Finding the correct temperatures for the feed plate and the plate above requires calculating the compositions with assumed temperatures. The calculations in Table 57 are made for assumed temperatures of 160 F and 205 F temperatures, the 160 F temperature for the plate above the feed being 10 F below the enriching section pinch temperature, and the 205 F temperature for the feed plate being 10 F above the stripping section pinch temperature. The difference between these assumd tempera-

tures is 45 F as compared to a difference of 25 F between the pinch point temperatures.

After assuming the temperatures of 160 F and 205 F, the compositions are computed by applying equation (95) to the C_1 and C_2 at 160 F and by applying equation (100) to the C_5 and C_6 at 205 F. The quantities of these four components in the vapor leaving the feed tray are found. Equations (95) and (100) apply to all components at the pinch zones because the compositions of all components are constant.

The quantities of C_3 and C_4 in these vapors are then found by material balances as shown in Table 57. With the vapor composition thus found, the feed plate temperatures of 205 F is checked, obtaining the liquid to the stripping section. The liquid from the enriching section is next found by subtracting the liquid portion of the feed. With values of l_n, the temperature of the tray above the feed is checked.

If a check had not been obtained, other assumptions would be made as to the temperatures and the calculations in Table 57 repeated.

THEORETICAL PLATE AND COMPOSITION CALCULATION METHODS

As mentioned earlier in this installment, there are five different types of fractionation calculation methods. These methods will be discussed in detail in later installments, and illustrations will be given covering their applications. At this point, it is worthwhile to look at the whole subject in a general way.

At the end of this installment, there are 29 references covering the published literature on this subject. The contents of these articles will be discussed later in more detail. Following is a brief review of the information that may be obtained from study of the articles given in this bibliography.

Plate-to-plate methods. The plate-to-plate methods are those of Lewis-Matheson[20] and Thiele-Geddes[24]. In the Lewis-Matheson method, computations are started at each end of the column and worked toward the feed plate with given compositions for the products to find the number of theoretical plates. In the Thiele-Geddes method, the number of plates are assumed and the product composition found by working through the column in terms of composition ratios and meshing the enriching and stripping section calculations at the feed plate. Hummel[16] proposed a modification of the Thiele-Geddes method. Cope and Lewis[8] carry out the plate-to-plate calculations graphically with an XY diagram for each component. This involves trial and error to make all diagrams consistent.

Short-cut methods. Short-cut methods have been proposed by Brown et al[2, 3, 4, 5] and by Gilliland[11]. The Brown method uses absorption and stripping factors whereas the Gilliland method uses relative volatilities and relative operating line factors.

Empirical methods. Brown and Martin[6], and Gilliland[12] developed empirical methods for estimating the number of equilibrium places at any reflux ratio for a given separation in terms of the minimum reflux ratio and the minimum number of plates. These methods do not give the location of the feed plate. In using them, it is necessary to have the minimum reflux ratio and the minimum number of plates that may be obtained by equations of Colburn[7] and Fenske[10]. The minimum reflux ratio is difficult to evaluate accurately for multicomponent systems.

Americans each consume about 15 bbl of petroleum products a year. Annual consumption per person in the rest of the world is only about ½ bbl a year. Canadians use 7 bbl, Mexicans 2 bbl, Russians 1 bbl, and the people of the Far East use only about 1/10 bbl of oil a year.—*The Petroleum Data Book*, Dallas, Texas.

☆ ☆ ☆

Graphical methods. Jenny[17,18] uses a modified equilibrium line drawn through a few points computed by plate-to-plate computations at each end of the section involved. With this empirical equilibrium line, the conventional operating line is employed and graphical steps are constructed. Hengstebeck[14] modifies the operating line rather than the equilibrium, obtaining the equilibrium line from the XY data on the key components being separated, and uses these two lines for constructing graphical steps.

Overall equation methods. Overall equation methods have been proposed by this author[9], by Harbert[13], by Smith[23], and by Underwood[25,26,27,28,29]. In this author's method, the calculations are made in terms of absorption and stripping factors, i.e. (L/KV or KV/L), using composition ratios and meshing the enriching and stripping section calculations at the feed point to compute the resulting products. Harbert and Underwood developed complex equations in terms of relative volatilities, which require for their solution the assumption of constant relative volatilities and constant reflux ratio. Smith developed a method of calculating the theoretical plates from the average temperature and reflux ratios for each section of the column.

In addition to the literature articles describing the different methods, the reader is referred to the text by Robinson and Gilliland[21].

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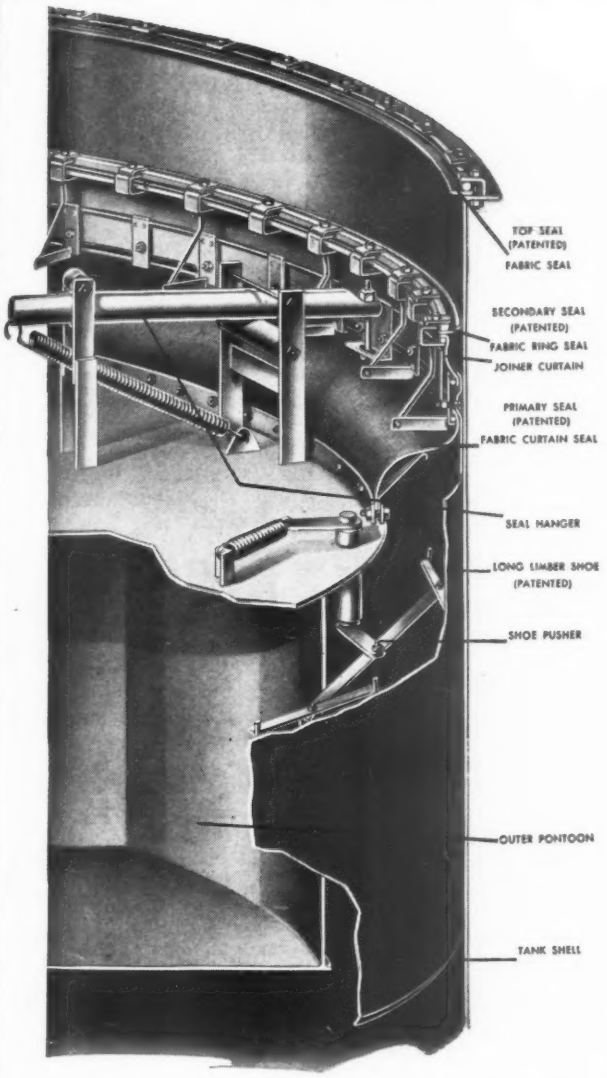

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WIGGINS BALLOON ROOF
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Asphalt—the "black sheep" of the petroleum industry

By C. M. HEWETT, Research Engineer
Mexican Petroleum Corporation

EXCLUSIVE

PETROLEUM asphalt has always been considered a "black sheep" in the oil industry. The average layman, when asked if he knows what asphalt is, will answer readily: "Sure, it is a black sticky stuff that comes from lakes somewhere in South America". Asphalt refined by nature from petroleum does come from that source, but practically all asphalt consumed today is produced from petroleum crude oils at petroleum refineries.

There are others who will advise that it is a by-product of the gasoline refinery. This is not true, even though a part of the petroleum asphalt produced is derived from crudes that are processed for their high yield of gasoline, light oils, and/or lubricants.

The yields of asphalt from semi-asphaltic crudes are often as low as 10 per cent by volume. Asphalts produced from Mid-Continent crudes are of this type. These asphalts are more waxy and have lower ductilities and contain less sulphur than those produced from typical asphaltic crudes.

It is also true that almost all asphalt produced is refined from oil known as asphaltic crude that comes from South America, Mexico, California, Arkansas, Texas, and other Gulf Coast states. These crude oils will yield from 35 to 70 per cent by volume of asphalt having a consistency of 85/100 penetration. The asphalt content of a crude is described as the per cent of this consistency asphalt contained when reduced by a prescribed evaporation procedure. The straight-run gasoline yield of some of these crudes will be as low as 4 per cent by volume.

There are a number of refineries that produce asphalt as their major product and they operate on asphaltic crudes or topped semi-asphaltic crudes. Their low production of naphthas and gas oils are largely utilized in preparing liquid asphalts, blended asphalt flux oils, etc.

The methods used to produce asphalt from petroleum are usually classified as atmospheric steam distillation, vacuum distillation, and a combination of one of these with air reduction or blowing.

In the conventional atmospheric unit the crude or topped crude is passed through a continuous pipe still in which its temperature is raised to between 650 and 800 F. From there it goes to a tower where the lighter oils are removed by vaporization with the aid of live steam, which is either injected into the heater tubes with the oil, or into the bottom of the tower, or both. The added steam decreases the temperature requirements necessary to reduce the asphalt to the desired consistency by its partial pressure effect and mechanically aids in stripping the heavier ends to produce a better flash point on the finished asphalt. The quantity of steam must, of course, be controlled by the process engineer because too much steam can be used, which would result in overloading the tower with vapor and cause excess velocities and pressures.

The overhead products are usually passed to other towers for further fractionation to make the desired specification stocks. The asphalt is withdrawn continuously from the bottom of the tower via exchangers to run-down tanks. The level of asphalt retained in the bottom of the tower is controlled by automatic float valves.

A very important point to remember in the refining of asphalt is that temperature-time relationship must be controlled sufficiently to prevent overheating of the asphalt. A temperature of 800 F is generally recognized as the cracking temperature, but asphalts may be overheated and fail to meet the "Oliensis" test for homogeneity, when subjected to temperatures lower than 800 F for progressively longer periods of time. The ability of asphalts to withstand the effects of weathering are indicated to be less with increased degree of overheating.

The vacuum distillation is very similar to the atmospheric operation, except that it permits, by the use of lower absolute pressures, the refining of asphalts from higher boiling crudes at temperatures below which overheating would occur. Some live steam is used in this operation in the same manner as in the atmospheric distillation in order to obtain desired stripping. In order to utilize these crudes with an atmospheric unit, decreased throughput and increased quantities of steam would be required. When charging asphaltic crudes to vacuum units the pipe still temperatures used are comparable with those of atmospheric units.

Air-reduced, or blown asphalts are produced by passing air through asphalts at elevated temperatures. This proces may be of the batch type in large horizontal or vertical stills and even larger tanks up to 10,000-bbl capacity; or the continuous tower process with air and asphalt flowing counter-current. The temperatures may vary between 350 F and 600 F. The actual temperatures used vary with the charge stock, the rate of oxidation desired, and the method used. Tank oxidation is usually conducted at the lower temperatures. This oxidation rate increases with the operating temperature. The maximum temperature used is limited by the flash point of the charging stock in order to stay within the limits of safe operation. The consistency of the charging stock may vary between a topped crude and a low-penetration refined asphalt, depending upon the final product desired. Blown asphalts, having higher penetrations, less susceptibility to temperature change, and lower ductilities for the same softening points, result from the softer, higher - penetration charging stocks.

Asphalts blown at low temperatures have more of a tendency to drop back in softening point if later heated for a short period of time at temperatures of 550 to 680 F than do those blown at approximately 500 F.

Another product marketed as asphalt, is known specifically as "pressure tar". It is produced by steam refining a residue or tar from cracking units by processes similar to those mentioned previously for producing virgin asphalts from crude oil. Blown pressure tars are also produced similarly to blown virgin asphalts.

These pressure tars are excellent materials for waterproofing, low-temperature saturation, binders, and coatings where they are not required to resist the effects of weathering. They are highly cracked materials and do not withstand the effects of exposure to the sunlight and air as well as most virgin asphalts.

A relatively new product sometimes referred to as asphalt, is the propane-extracted residue. This material is produced by the batch or continuous method in which the oil is brought into contact with propane in ratios of oil to propane that vary from one to two up to one to seven and temperatures between 130 to 200 F. By changing these conditions, residues are obtained that vary from zero penetration up to hot oil, or float consistency.

These residues are obtained as by-products from a process designed to reduce the Conradson carbon of gas oil stocks for use as catalytic cracking unit charge stocks, or to improve the quality of lube stocks by removal of the resins and asphalt-like materials that are undesirable in these stocks. The residues have very high susceptibility to temperature change, high ductilities at 77 F. and are usually low in asphaltenes. Most of their physical properties are in-between those of pressure tars and steam refined virgin asphalts.

The storage and handling of asphalts require special equipment. Practically all lines in asphalt service should be

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- ☐ Drilling test holes
- ☐ Filling water tanks on seismograph trucks

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- ☐ Oiling down lease roads
- ☐ Tank bottoms to slush pits for disposal
- ☐ Filling tank trucks with water for initial treaters, indirect heaters, radiators, etc.
- ☐ Transferring tanks (leaky tanks, bad oil; for repairs, cleaning, etc.
- ☐ Transferring salt water
- ☐ Cleaning up oil lease: line breaks, tank leakage
- ☐ Circulating tank bottoms through treaters
- ☐ Circulating bad tanks through treaters
- ☐ Pumping from tank or treater to slush pit
- ☐ Driving chemical feed pump
- ☐ Draining treater for cleaning
- ☐ Domestic service around lease houses
- ☐ Cleaning B.S.&W. from tanks (heavy)
- ☐ Cleaning B.S.&W. from tanks (light)

PIPELINE OPERATIONS AND MAINTENANCE

- ☐ Cleaning up oil lease
- ☐ Pumping out sumps
- ☐ Removing water from pump houses
- ☐ Dewatering for repairs
- ☐ Salvaging oil in event of line break
- ☐ Transferring tanks in case of leaks
- ☐ Gathering systems (lower pressures)

PIPELINE CONSTRUCTION

- ☐ Dewatering
- ☐ Water supply to equipment
- ☐ Washing down equipment
- ☐ Pumping station foundations

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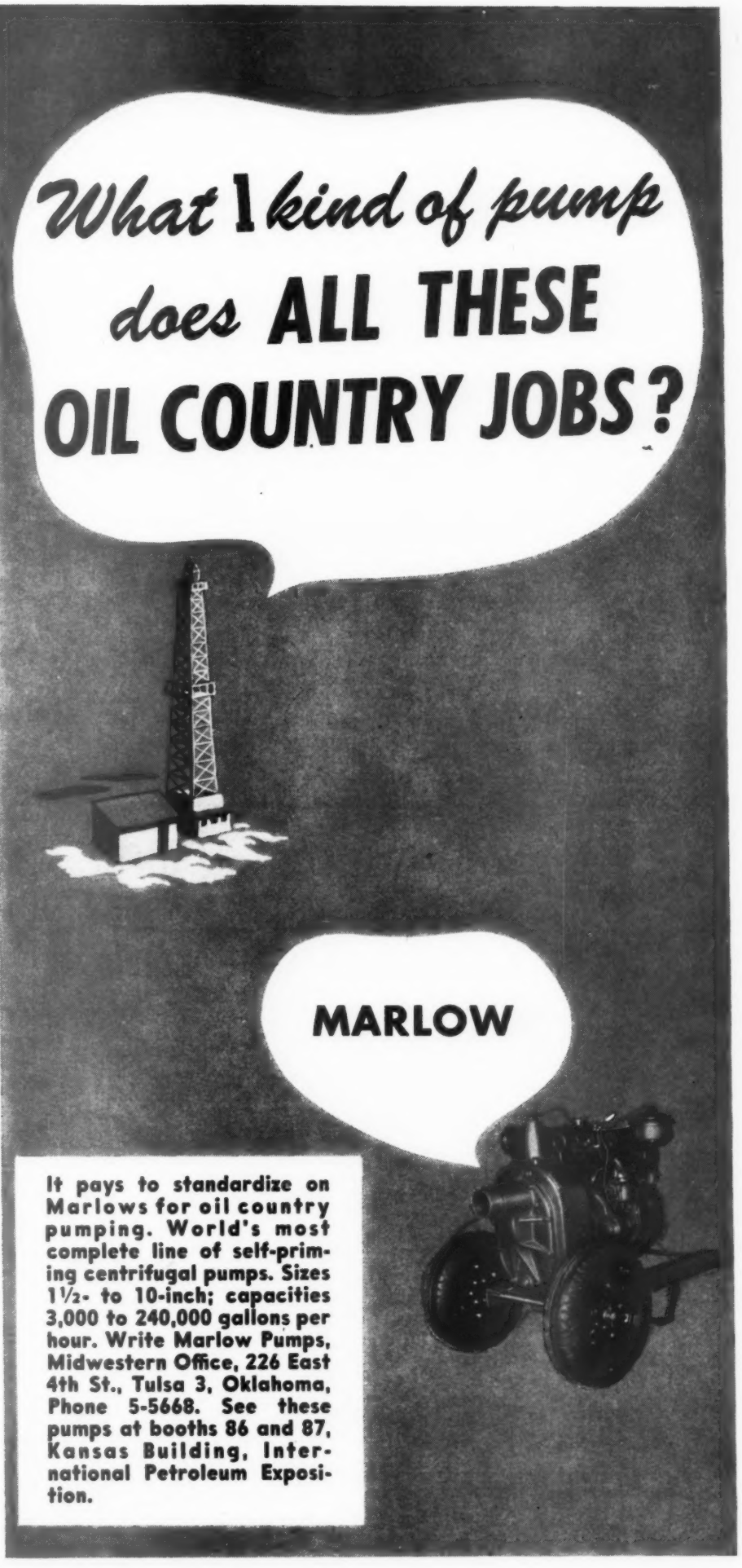
- ☐ Pumping out sumps
- ☐ Water transfer
- ☐ General waste pit pumping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insulated and any required for handling penetration grade asphalts are heated by a steam-tracer line outside, or a "gut" line inside, the pipe line. The latter, although efficient, is difficult to repair. The lines are usually blown out with air after each movement. The pumps for handling asphalts also should be steam jacketed. Tanks for storage of asphalt products should contain steam coils, or other heating elements, to permit carrying the stocks at the temperatures required to pump readily. These temperatures will vary from 100 F for light liquid asphalts at summer air-temperatures, to 350 F for oxidized asphalts of plus 150 F softening point, even in the summer. All tank cars for transfer of asphaltic products should contain steam coils and be insulated for penetration asphalts.

Asphalt, which is looked upon by many as the "black sheep" of the petroleum industry, is probably more versatile than any other single petroleum product. It serves the needs of the public in hundreds of ways. Asphalt is used in roads and streets as binder in asphalt pavements; fillers in brick pavements; expansion joints, crack filler, and underseal for Portland cement concrete pavements.

This use of asphalt for under-sealing Portland cement concrete pavements has developed within the last six or eight years. When a concrete pavement, after serving its purpose a few years as an adequate road, begins to show signs of distress as evidenced by pumping, it may yet be reclaimed by forcing asphalt beneath the concrete slab. After such treatment the concrete will also serve as an adequate base for an asphalt-surfaced road to give many years of satisfactory performance. The asphalt used for under-sealing is usually oxidized and has a softening point of 165 to 200 F and a penetration of 20 to 35 (100 grams, 5 seconds at 77 F). It is pumped beneath the pavement through holes drilled into the surface. Asphalt temperatures of 350 to 400 F and pressures of 20 to 35 psi are normally sufficient for this operation. Millions of gallons of asphalt are being used each year for this purpose.

More than 2,000,000 tons of asphalt were used by the roofing industry in 1945 and consumption of asphalt by this industry has shown a termendous increase in the last two years. It is used as saturant, coating, and adhesive in the production of built-up roofing, shingles, sidings, cements, etc.

Asphalt is used in the production of rubber and molded products as fillers and binders, in the production of linoleum, asphalt-tile, electrical wire and cable coverings, battery boxes, paints and enamels. It is used to moisture-proof laminated-paper bags and fiber cartons. In some of the latter, for use in packaging foods, etc., a very minute film of low-staining asphalt is utilized.

Large quantities of asphalt and asphaltic compounds are consumed in the production of pipe line coatings to resist corrosion caused by chemical and electrolytic action set up in the soils surrounding these underground lines and conduits. Also, several hundred thousand tons of asphalt are consumed each year as a binder in the coal-briquetting industry.

This presents briefly the versatility of this "black sheep". Research in this field is daily producing new uses for this product and the demand for it is continuing to grow like the proverbial "beanstalk". ★★★

Esso cuts prices

Esso Standard Oil Company March 29 cut prices on farm tractor fuel, bottled gas, roofing asphalts, and 325 lubricants.

Reductions ranged from 0.5 cent a gallon on farm tractor fuel to as much as 25 per cent on some grades of lubricants.

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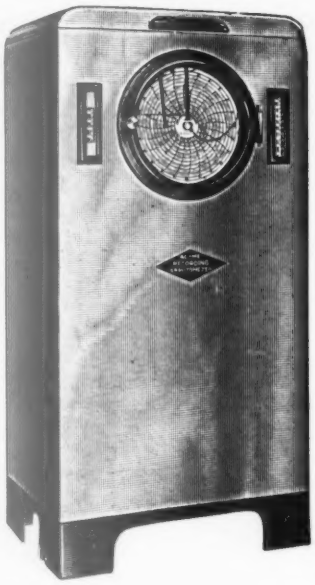

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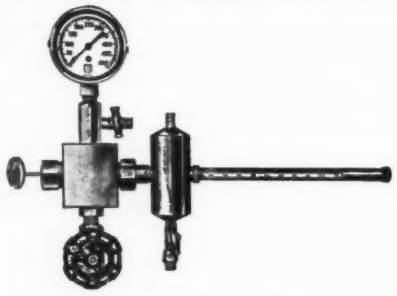

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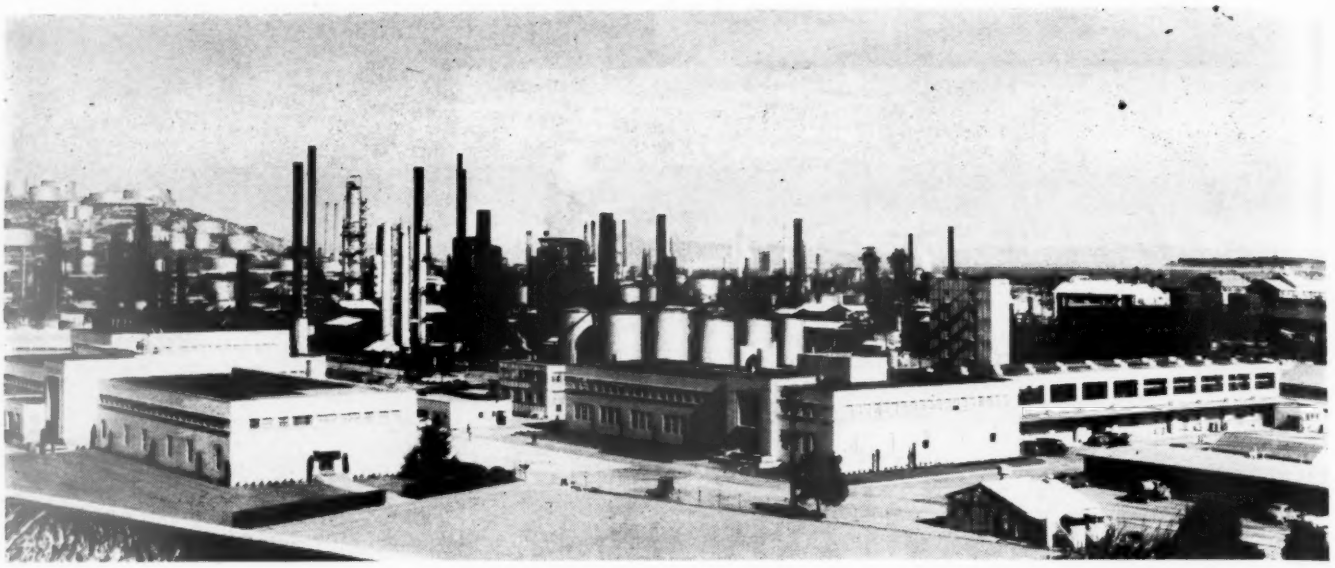

Panoramic view shows completed $2,000,000 laboratory program of California Research Corporation (a subsidiary of Standard of California) in Richmond, California, with Richmond refinery in background. The Cal Research buildings are, left to right:

Research Laboratory "A," which houses administrative offices and general laboratories;

Research Laboratory "C" (one-story building to rear of "A"), for industrial lubricant research;

Engine Laboratory "A," for testing engine lubricating oils;

Process Laboratory "A," which includes cold room and facilities for process research studies using pilot plants;

Process Laboratory "B" (seven-story structure in rear of PL "B"), for tall pilot plant operations.

Low buildings at extreme right are auxiliary process laboratory units.

Expanded project covers more technical research

By RICHARD SNEDDON, *Pacific Coast Editor*

IN celebration of the completion of its postwar expansion program, California Research Corporation recently held open house at its Richmond laboratories, and along with sundry other representatives of the press we were the guest of H. G. Vesper, and his battalion of scientists in one of the most interesting sightseeing afternoons of a long sightseeing career. California Research Corporation, a Standard of California subsidiary, has just spent some $2,000,000 adding the last touch of modernity to this already distinctly modern institution, and it is now a most impressive indication of whither the oil industry is trending. If there remains anywhere a doubt that we are now entering the scientific era of petrolic operation, this intriguing assembly of twisty tubes, weird machines, superman gadgets, and calmly confident young supermen, should quickly dispel it.

EXCLUSIVE

The major parts of the expansion project involved the construction of a large two-story process laboratory, an extension of the main administration and research laboratory building, and the installation of additional facilities for the 675 employes who constitute the Richmond staff. As the complete institution now stands, it is comprised of 34 buildings with a total floor space of 175,000 sq ft; 80 individual laboratories, and 125 separate offices. But it might be noted that while the buildings, architecturally and otherwise, are altogether attractive and studiously convenient, it is what goes on inside them that really creates excitement.

The research program, simply stated, is just a continuous search for new and improved products from petroleum, and better ways of making them. It is theoretically divided into three categories: (1) Basic Research, or the search for new ideas; (2) Development, or the search for means of improving ideas already formulated, and (3) Technical Service, or the search for answers to the technical problems of refiners, oil field operators, marketers, and customers. These categories, of course, each fan out tremendously, and keep fanning out indefinitely, so that the coordination and correlation of all the multitudinous activities that are carried on becomes an administrative problem of considerable magnitude. It is obvious even to the most casual observer, however, that despite the strange character of many of the individual investigations, the general scheme of operation follows an orderly pattern and is under very capable direction.

It is interesting that the main building in the Richmond group was erected on piles, because it is located on land that was originally reclaimed from the bay. The water table in Richmond is just three feet below the surface of the ground, and it was thus necessary to run drainage pumps continuously throughout the construction period. The building, which is three stories high with a waterproof basement, houses a group of laboratories on the first floor, and the various offices on the second. It features the latest type of air conditioning, in which the refined air is given a slight alkalinity in order to keep down to a minimum the corrosion of highly delicate and sensitive precision instruments.

In this building are the conference rooms designed for the conduct of joint discussions in closed session; the accounting and clerical offices; the technical files—mostly stored in a fireproof vault, and including virtually all the technical reports of the laboratories back to 1919; the library, lunchroom, stockroom, and other departments and compartments, all essential to the achievement of the ultimate function. Special mention might be made of the library, which currently subscribes to 260 journals and has on its shelves about 4000 bound publications and twice that many

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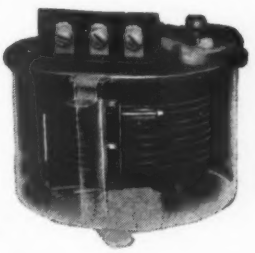

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unbound ones. It boasts 20,000 U. S. patent specifications and 5000 foreign ones, besides 3000 reference texts and 15,000 pamphlets and bulletins of various kinds. The library conducts patent searches and technical literature searches, for the chemists, physicists, and engineers in the laboratories; publishes weekly abstracts of pertinent material appearing in current technical magazines, and employs a translator to search the technical literature of Germany, France, Italy, Portugal, Holland, and Russia.

The general design of the individual laboratories in the new buildings is patterned after those in the main building, which were originally designed in 1939. In planning, emphasis was placed heavily on the safety factor. This was especially important, because of the nature of the materials with which the staff is required to work. A high rate of air flow through the air-conditioning system is a guaranty against the building up of explosive mixtures through leakage or spillage of highly flammable and volatile materials. A fire, if it did develop, however, could be easily handled by the laboratory occupants with the aid of carbon dioxide extinguishers, placed at the two doors with which each suite of rooms is provided. There is a safety shower in every laboratory and a fire blanket also within easy reach. Natural gas piped in to the benches can be shut off immediately in case of emergency by a quick closing valve situated near the door. All electrical circuits may be disconnected at will by means of a handy master switch, and the fire alarm system and emergency lighting system, normally operated by a.c., can be promptly switched to d.c. in case there should be a power failure.

There are three cold storage rooms, one operating at 30 F, a second at minus 40 F, for the storage of unusually volatile samples, and a third one, functioning as a laboratory, capable of being carried down to minus 50 F. A small anteroom removes most of the moisture from the air and serves as a cold air lock. The doors can be opened from both sides and there is an alarm system to bring immediate help should the doors freeze or other serious contingency develop. The cold rooms permit the testing of lubricating oils, greases, fuels, and, indeed, any commodity that is destined for use in areas or countries with low winter temperatures. Operations can be carried on under a variety of accurately simulated conditions, and in dimensions that come much closer to actuality than do the usual scale laboratory tests.

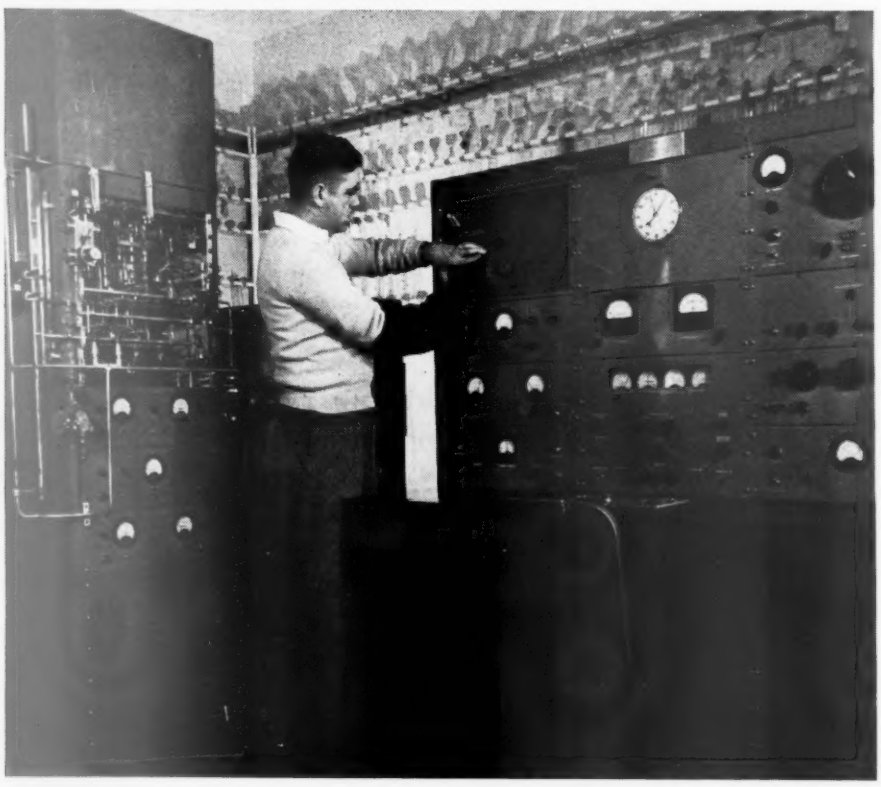
Having explained all this and much more, our guide, a pleasant laddie by the name of John Spence, hailing originally from Glasgow, Scotland, convoyed us to the special equipment laboratory where we witnessed a colorful stroboscopic exposition, entitled "stopping motion with light." By means of intermittent light, this instrument made a rapidly revolving fan appear to stand still, and by the queerest coincidence, in doing so brought out the cryptic sign "RPM" emblazoned on the blades. Besides stopping motion with light, we took a look at our singing voice via a microphone and oscillograph. An electric current reproduced the sound intensity of the warbling, and projected it on the screen of a television type tube, and if we do say so ourself a bit immodestly, our singing looked very nice—much better than it sounds.

Next stop in our tour was the glass blowing shop, and this was almost embarrassing, particularly to an ex-chemist who used to ruin fifteen dollars worth of glass every time he made a nozzle for a wash bottle. Here were to be seen some of the most intricate pieces of equipment, beautifully finished, and made right on the premises. The blowers start out with glass tubing, flasks, ground joints, and stopcocks, which are purchased in ready made form. With these materials and rough sketches they then fabricate the most complicated pieces of apparatus. A glass blowing lathe is used on large, complex pieces that are too unwieldy for hand manipulation. This lathe supports and revolves the glass, leaving the operators hands and feet free for control of the flame and blowing. The finished work is then conditioned in an annealing furnace that slowly heats to a predetermined temperature. In an adjoining room are individual benches, burners, and spinning machines, where routine work is done, and smaller assemblies are built.

Thence we entered the petroleum processes laboratories and examined the intricacies of solvent extraction, here being carried on in an all-glass unit so that every stage of the process was visible. The refining is accomplished by dispersal of the feed stream into small droplets, during contact with a solvent that itself is insoluble in the feed stock, and yet is capable of selectively dissolving the undesirable constituents. The feed and solvent streams are flowed in opposite directions, the former entering at the bottom, being then dispersed by a packing of glass beads, and finally rising through the more dense solvent that enters at the top of the fractional column. The progressive refinement is evident in a graduation of color along the column, at the top of which the refined oil collects and overflows to the receiver.

In an adjoining laboratory was a piece of apparatus set up to reveal the mechanism of the California polymerization process. In cracking heavy petroleum oils, either thermally or catalytically, for gasoline manufacture, one of the by-products is a rather large quantity of hydrocarbon gases that, as is, are not suitable for use in conventional automobiles or airplanes. A large part of these gases is olefinic, and the method here disclosed polymerizes the olefins into high quality liquid gasoline. The process involves heating the gases after purification, and passing them over a catalyst.

Harvey Norman removes the photographic record from the mass spectrometer indicating the complete composition of a sample petroleum product. This instrument, which costs in excess of $25,000, is the type used by the government in the separation of Uranium 235, a key to the development of atomic energy. It is one of the many complicated pieces of equipment found at Richmond laboratories.



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The small molecules of gaseous olefin when activated by the catalyst react with each other to form larger polymer molecules. These are liquids in the gasoline boiling range, and have a high octane rating.

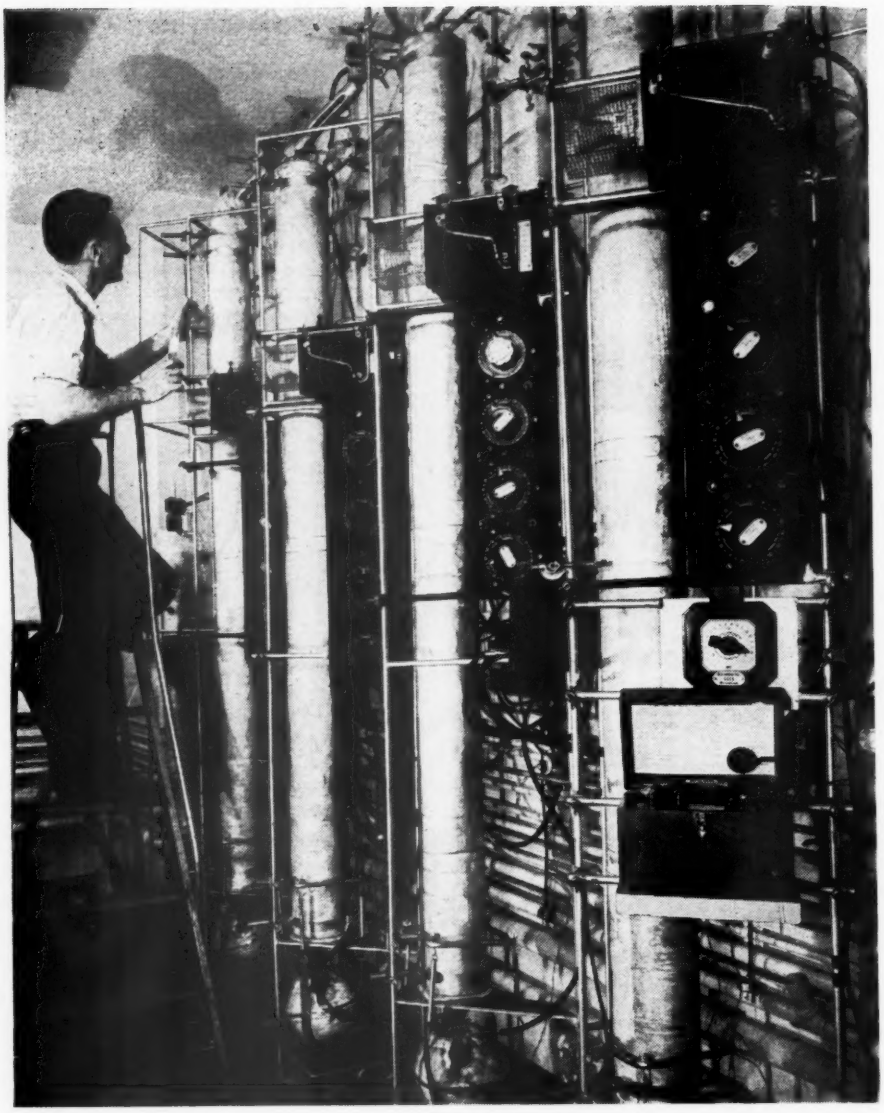
Next on the schedule was the physical measurements department, wherein is conducted research and development work on new test methods, and analyses of unusual substances originating from the other laboratories. First demonstration was a modernized version of the old combustion train for determining the percentage of carbon and hydrogen in organic compounds. We noted that it was more upright than horizontal, and didn't have as many places to leak as the ones we used to assemble 20 years ago. Then there was the power factor bridge for testing the ability of mineral insulating oils to minimize power loss through insulation on power transmission cables. Finally, in this section was a battery of viscosimeters of various types, used to check the SAE number of lubricating oils, and, of course, in many research investigations.

Continuing under the direction of our well informed guide, we found an exceedingly interesting pair of miniature manufacturing plants in the chemical process labs. The first one was showing the process of synthesizing from a petroleum product, called alkane, an unusually effective detergent. The sequence of events was to sulphonate the alkane and neutralize the resulting sulphonic acid with caustic. The product of neutralization is the synthetic detergent, which is ordinarily compounded with other ingredients to develop the specific properties required in the particular application for which it is being made. The second plant was manufacturing phthalic anhydride on a small scale from ortho-xylene by the same method that is employed commercially. That is, ortho-xylene, obtained from petroleum, is pumped into a vaporizer. Air meets the xylene in the steam-heated vaporizer and the vaporized mixture then passes through the catalyst bed in the reactor, where the ortho-xylene is partly oxidized to yield phthalic anhydride. The hot gases emanating from the base of the reactor are passed into a condenser to crystallize the anhydride, after which it is purified by distillation.

Our itinerary then took us to the industrial lubricants laboratory, where studies are made of the properties of such products as greases, gear oils, turbine oils, cutting oils, etc., and of the methods by which such properties may be best evaluated. Here were to be seen oxidation tests, corrosion tests, oiliness tests, wear tests, and all the miscellany of tests to which lubricants of wide variety are subjected. There were special oils of unusual characteristics undergoing investigation, and in the mechanical department a number of new type testing machines in the process of construction.

In the petroleum products laboratory was an exhibit showing how grease is manufactured by the batch process. Typical grease ingredients, the preparation of soap concentrates, the blending of soap and oil, and samples of the resulting products were on display. The modus of determining grease consistency, and the effects of hand working and machine working on consistency, were also demonstrated. In another corner was shown the apparatus used in electron microscopic studies of soap fibers in grease. This is done by evaporating an infinitesimally fine film of gold on to the soap fibers, rendering them more opaque to the electron beam. Typical electron micrographs of grease fibers were shown. Oxidation susceptibility of grease was determined by measuring the drop in the pressure as oxygen reaction takes place in a closed chamber. Next door was a highly interesting example of grease manufacture by a continuous process. It was all very simple! Oil and soap concentrates were pumped into a soap mixer from which the finished grease was promptly discharged.

Leaving the oil and grease experts, we walked in on a group of electronic engineers, or physicists, or whatever they are called, and looked knowingly at an X-ray diffraction device that analyzes very quickly by the crystal structure of the components in the sample. It is used in observations on corrosion and the



These four columns are precision distillation equipment used in the development of new and improved chemical products from petroleum. The operator is Homer Wellman of the Richmond laboratories of California Research Corporation.

Truck survey

For-hire truck operators are being surveyed by the National Tank Truck Carriers, Inc., to determine the number of liquid petroleum gas tank trucks now in operation.

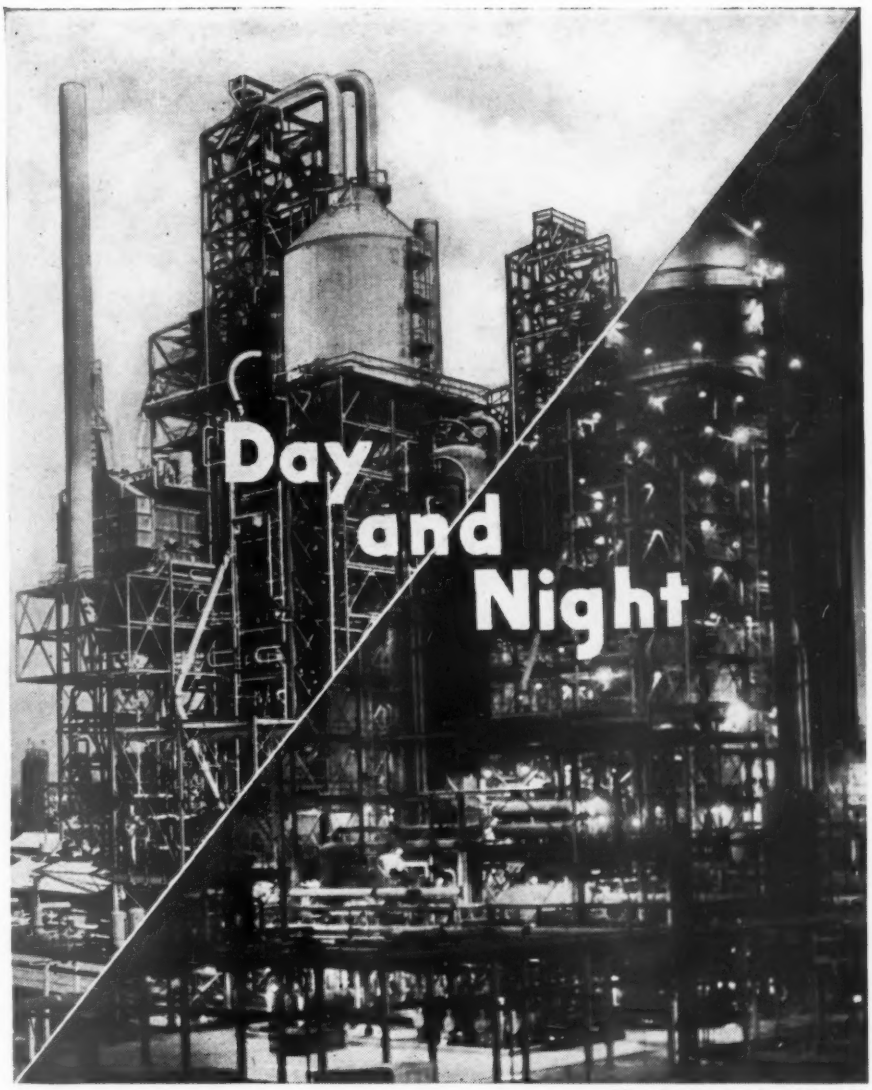
According to C. Austin Sutherland, secretary-manager, the information will be used to determine future haulings to both butane and propane gas in view of continued shortages expected for these products and will supplement the National Petroleum Council's steel requirements report from the petroleum industry.

products of corrosion; the behavior of catalysts, and the nature of unknown residues developed in refining operations. In this department also was a Geiger counter clicking off emanations, radiations, and disintegrations with an abandon that was easy to see but difficult to understand. The counter has its function in the fact that radioactive isotope carbon gives off a very soft beta ray, and is used to trace reactions between hydrocarbons of the types found in petroleum.

Nearby was a laboratory for Emission Spectrograph analyses. This amazing instrument can detect some 70 metallic elements in various solids and liquids with what is known as the "grating spectrograph." A sample of an engine deposit, corrosion product, or a used lubricating oil, for example, is burned between special graphite electrodes. The ruled grating receives the resulting light, disperses it into all the component colors, and brings each to its own focus on a 35 mm film. With a projection densitometer, the positions and blackness of certain spectral lines on the film are measured to provide a chemical analysis of the sample in an elapsed time of about one hour, and with an average deviation of from 5 to 10 per cent of the amount present.

Thence we came to a large laboratory containing equipment and machines for arriving at the performance characteristics of motor oils. Here were small single-cylinder engines of several types, larger single-cylinder engines, and full scale automotive tractor and industrial engines. Tests run in these engines determine such factors as engine wear, corrosion (bearing), and engine deposits. When present enlargement plans are completed this laboratory will have more than 30 diverse test units. Nearby was a laboratory in which was a crude oil distillation pilot plant. This is mostly used

"Seasick Wheel" is what scientists call this rotating device made to duplicate a ship's rolling motion. It is used to determine effects of tanker shipment on liquid petroleum products. Shown watching the test is Paul Condit.



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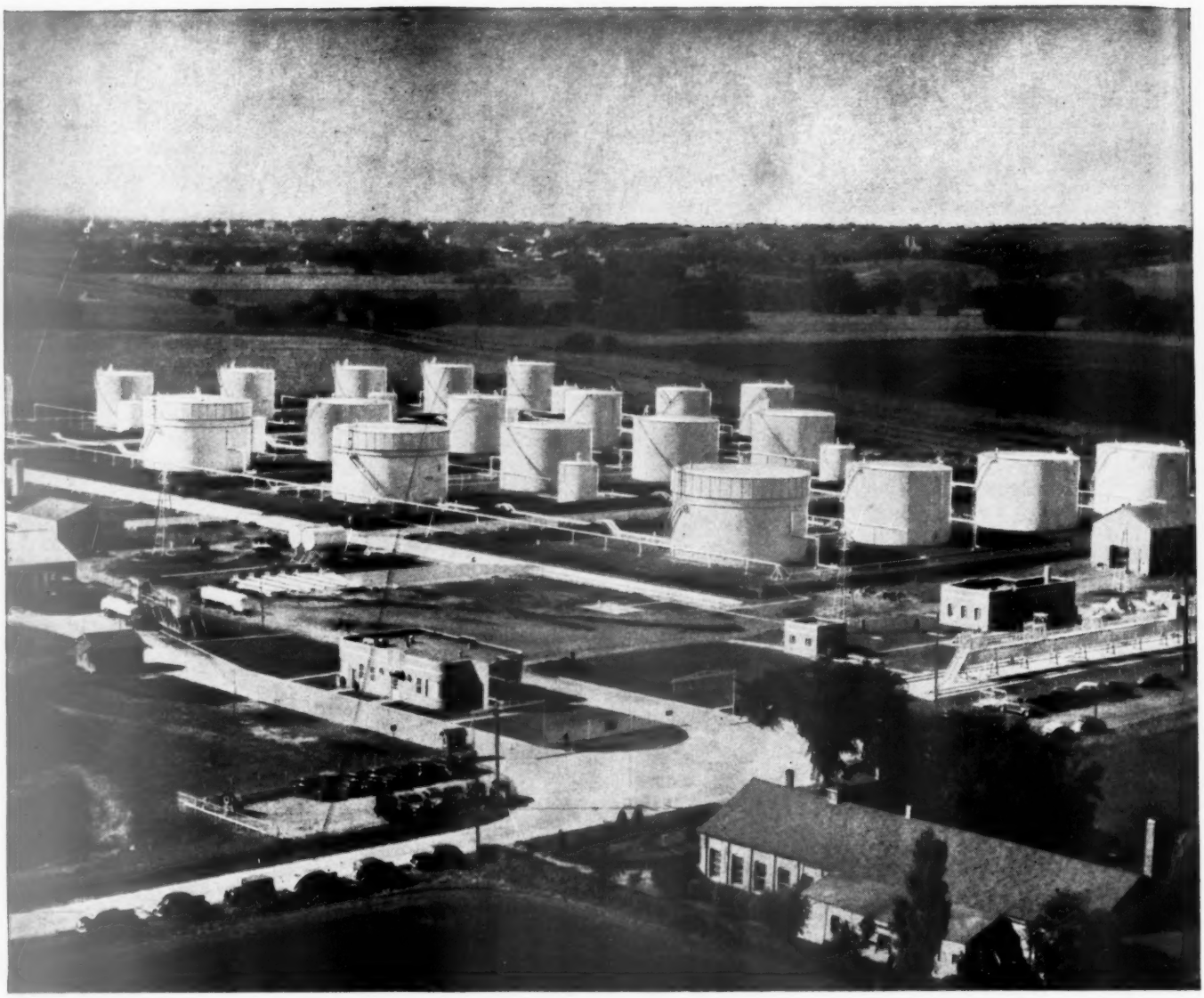

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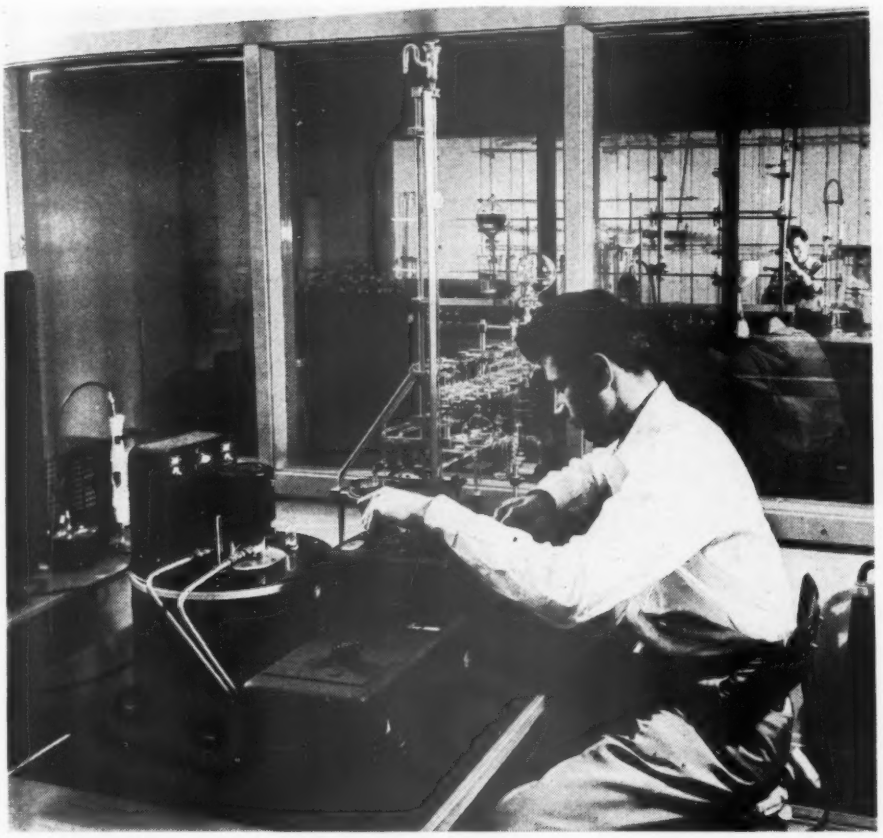


This compact instrument is an infra-red spectrograph photometer, which is used to determine the chemical composition of a petroleum sample. Operating the instrument is Arnold Abrams of the Richmond laboratories.

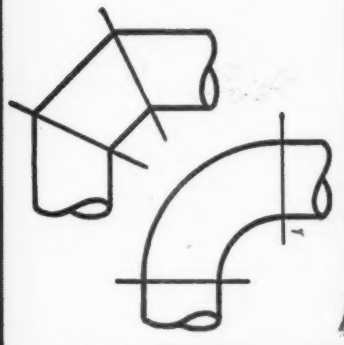
to find out how new and unfamiliar types of crude oil may be expected to react to the normal refinery process of which it is a small scale duplicate. It is also used, of course, to make special stocks for experimental purposes.

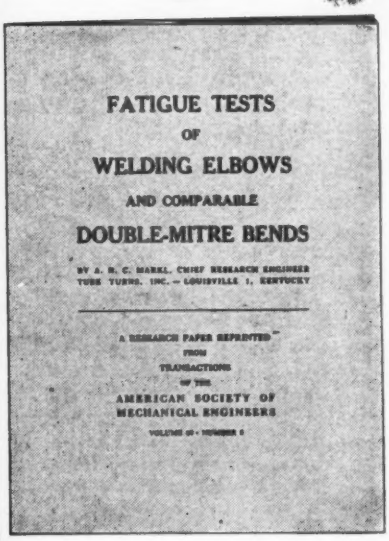
In the engine fuel research department is a single-cylinder gasoline engine equipped with a cylinder head of quartz plate, so that combustion can be actually observed. This cylinder head was designed and built by Cal Research. It is used in conjunction with a stroboscope to record photographically the combustion process at any stage in the engine cycle. An oscillograph is connected to a Calstan magneto strictive pick-up unit mounted in the cylinder head of the engine, and by this means such phenomena as detonation and pre-ignition can be intimately observed.

In the surface-active agents evaluation laboratory are instruments and machines for obtaining performance tests of surface-active agents. These are of three types—detergents, foaming agents, and wetting agents. Some agents may exhibit two, or even all three of these phenomena, but in any case they are now derived from petroleum and consequently form an important item in the research program. Detergents are tested by actually using them in washing fabrics under strictly controlled conditions. The degree of whiteness of the washed cloth is measured by a reflectometer. This instrument records by means of a photo-electric cell the extent to which a cloth sample is illumined by a constant light source, when the cloth sample is placed in the objective. As might be expected, the cloths, cotton or wool, may be soiled with either oil or non-oily dirt before being subjected to the washing test, to determine the efficacy of the detergent under various conditions. Foaming and wetting tests are conducted continuously in this department, too, and it might be mentioned in passing that one of the interesting applications of wetting agents is to assure an even distribution of the color in the dying of fabrics.

So we might have gone almost indefinitely from one exciting demonstration to another. The research chemist is the natural enemy of waste. Relentlessly he chases down every unprofitably attached radical and ties it into some useful function. To him, the applications of petroleum are limitless. Each fresh discovery is merely an indicator of new paths to pursue—new triumphs to win. The California Research Corporation's facilities at Richmond, and, indeed, all over California, are the symbol of faith that might well be interpreted for the edification of the layman. While sceptics bemoan the scarcity of new reserves, and wring their hands over the future of the industry, here is an optimistic organization of young, competent scientists, synthesizing, if you please, its own destiny, and that of the great organization of which it is a part. ★ ★ ★

WHICH?
and Why





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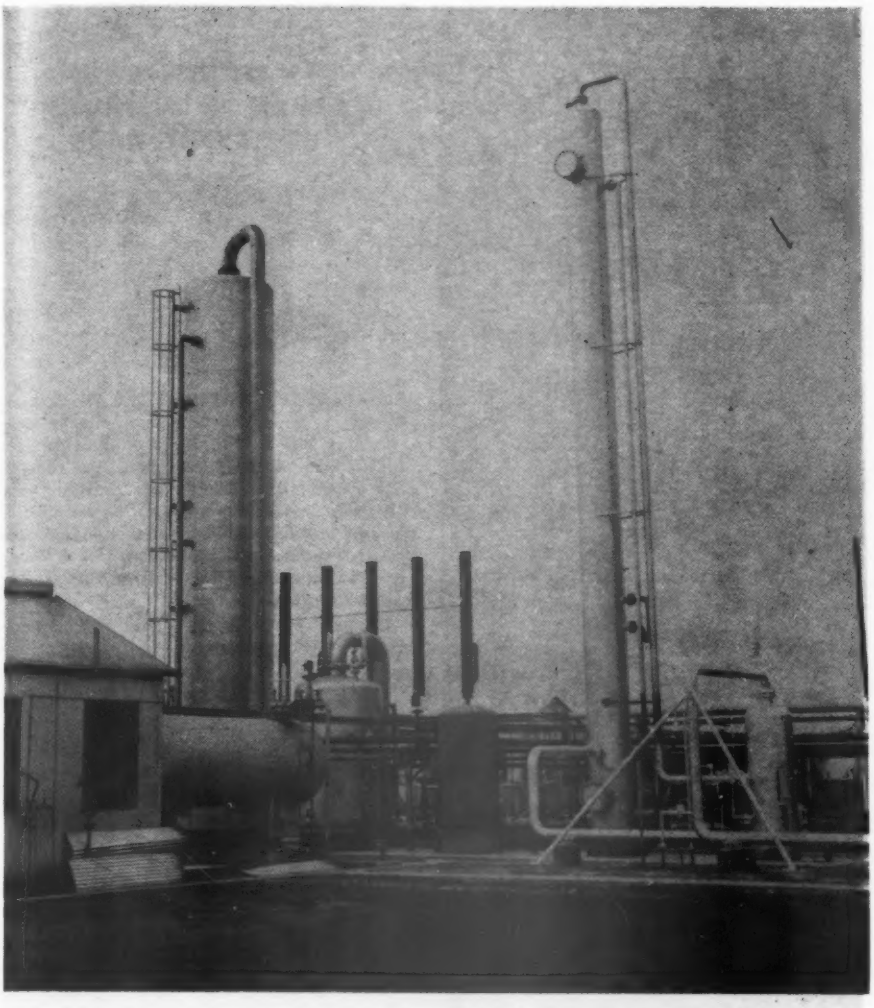


High pressure absorber is shown at right with residue scrubber at left. At the bottom of the page is an inlet gas scrubber equipped with automatic dump valves and liquid-level shutdown.

Pressure maintenance and high pressure absorption

By FRANK H. LOVE, *Managing Editor*

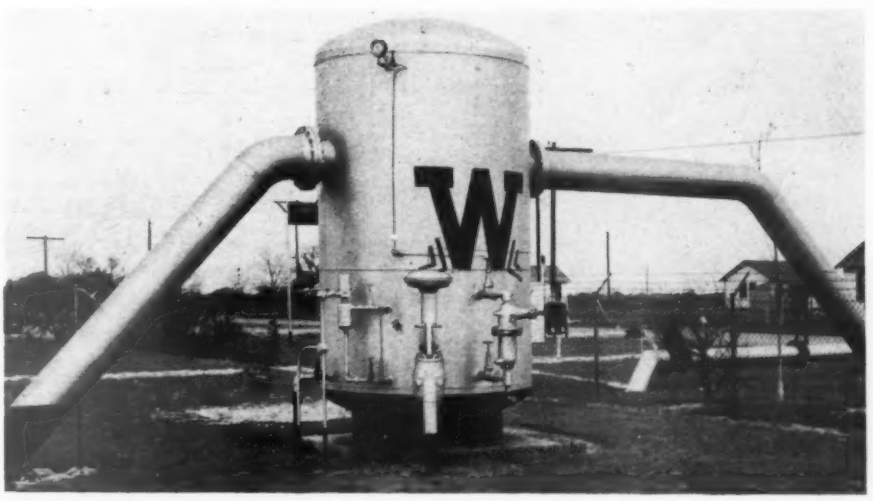
COOPERATING with operators in the Fairbanks field, Harris County, Texas, Warren Petroleum Corporation has installed equipment at its gasoline plant for the pressure maintenance of wells. After the completion of the repressuring equipment, high pressure absorption facilities were provided for recovery of additional hydrocarbon fractions.

EXCLUSIVE

This extension of its facilities, constructed on the site and in conjunction with a low pressure absorption plant, which was built in 1939*, is resulting in the injection of approximately 10,000,000 cu ft a day of residue gas and a substantial increase in the output of manufactured products — 14-lb RVP gasoline and 100-lb RVP butane-propane mixture. Also, more than 40 wells are being flowed by gas lift with another 4,000,000 cu ft a day of residue gas. Already in excess of 2,000,000,000 (billion) cu ft of gas have been injected into key wells, and as a result of the improvement in bottom hole pressure the Railroad Commission of Texas has increased the field's allowable substantially.

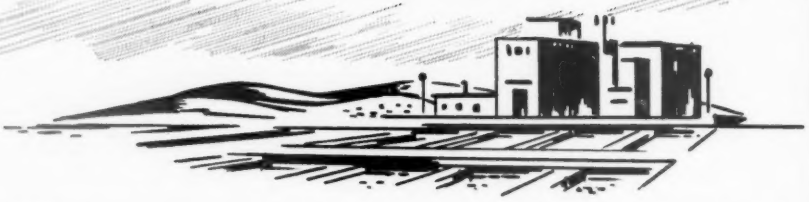
Approximately 28,000,000 cu ft a day of casinghead gas is being taken by the plant. The gas stream is split, 14,000,000 cu ft going through the low pressure (40 psi) absorption system. A part of the residue gas from this system is used in carbon black manufacture, approximately 8,000,000 cu ft being sold to the Columbian Carbon Company, which has a plant two miles east. The remaining 6,000,000 cu ft is used for plant and lease purposes.

Of the total volume of gas received by the plants this leaves 14,000,000 cu ft a day to enter the suction of the six 600-hp angle type compressor units provided for pressure maintenance and gas lift purposes. The gas enters the 10¼-in. cylinders of the compressor units and first stage discharge is at a pressure of 140 psi. After being cooled in the primary coolers the gas enters the second stage suction, is compressed by 7¾-in. cylinders and discharged at a pressure of 550 psi. The gas then passes through the second stage coolers and into the high pressure absorber where it is stripped of gasoline and light hydrocarbons. The stripped gas is returned through a residue scrubber to the third stage suction of the compressors, entering 4¾-in. cylinders and being discharged at 2100 psi. About 10,000,000 cu ft of the 2100-psi gas is returned to the field for injection into three key wells. The remaining 4,000,000 cu ft, less extraction loss, is reduced in pres-



*"New Plant Equipped to Manufacture Natural Gasoline and Butane," Frank H. Love, *The Petroleum Engineer*, August, 1939.

Important FACTS ABOUT pH for Oilfield and Refinery Engineers



WHETHER YOU ARE building a new plant or modernizing present equipment, one of the most important advancements you can make is the installation of BECKMAN pH CONTROL. Through the magic of accurate pH control you can make *many* vital savings... savings that will quickly pay for the installation and will *continue* paying big dividends throughout the years. For example, some of the many benefits resulting from Beckman pH Control include...

- Better control of gel rate, gel strength and shale dispersion in rotary drilling muds.
- Reduction of scale and corrosion in all types of steam boiler operations.
- Reduction of corrosion from acid crudes on costly refinery equipment.
- Better control of product quality in various types of refining processes.

...and many other important savings in modern field, refinery and laboratory operations.

BUT TO MAKE CERTAIN you get the latest, most convenient and most accurate pH equipment available, *be sure to specify* "BECKMAN"...

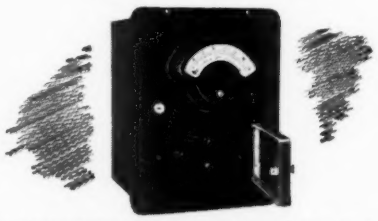
Beckman pH equipment is completely electrometric, eliminating the mess and inaccuracies of colorimetric methods. Simply press a button and the exact pH of any process is instantly shown on a large easily-read dial. *It is the simplest of all pH methods!*

The accuracy of Beckman pH readings is completely unaffected by human errors in color judgment, by turbidity, oxidizing or reducing agents, by suspended materials, colored process solutions or other variables that affect outmoded colorimetric methods. *Beckman pH readings are universally accurate and dependable!*

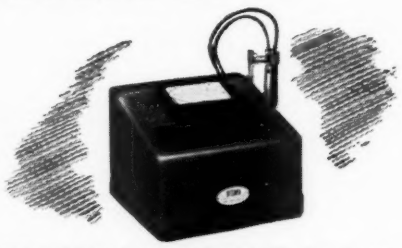
With Beckman equipment no time-wasting or troublesome sampling devices are needed. Beckman pH electrodes may be installed directly in vats, tanks, channels or flow lines—and exact pH values read instantly—and continuously, if desired—on the process fluids themselves.

Unique rugged-type Beckman Electrodes, specially designed for direct immersion in abrasive or suspension-laden fluids, reduce maintenance to an absolute minimum. *Beckman is the most trouble-free of all pH equipment!*

THERE'S A BECKMAN pH INSTRUMENT FOR EVERY NEED



COMPLETELY AUTOMATIC! The Beckman Model R instrument operates directly from standard 110 v. A.C. lines to provide completely automatic pH indication. Also provides for completely automatic pH recording and automatic process control. Can be installed to give accurate pH readings from various stations in plant through one instrument. *This is the pH unit being installed by today's most modern plants, large and small.*



PORTABLE A.C. OPERATION! The Beckman Model H instrument can be quickly moved from one part of the plant to another and plugs directly into standard 110 v. 50/60 cycle A.C. current. Compact, convenient and extremely simple to operate, the Model H gives instant pH readings on an easily-read dial. It is widely used both for manual pH control of small plants and as an auxiliary instrument on completely automatic pH installations.

COMPLETELY SELF-CONTAINED! The Beckman Model M is the ideal pH instrument where *complete* portability is desired. Operating from its own self-contained, long-life power supply, the Model M can be used *anywhere* in the plant or field, whether convenient to power lines or not. Features the same accuracy, simplicity and operating speed as the Model H, and is also widely used both for manual pH control of small plants and as auxiliary equipment on large automatic installations.

Write for literature on Beckman pH Equipment!

BRING YOUR pH PROBLEM TO US. Our trained engineers will gladly study your problem and recommend the equipment best suited to your particular requirements. No obligation, of course.

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BECKMAN INSTRUMENTS

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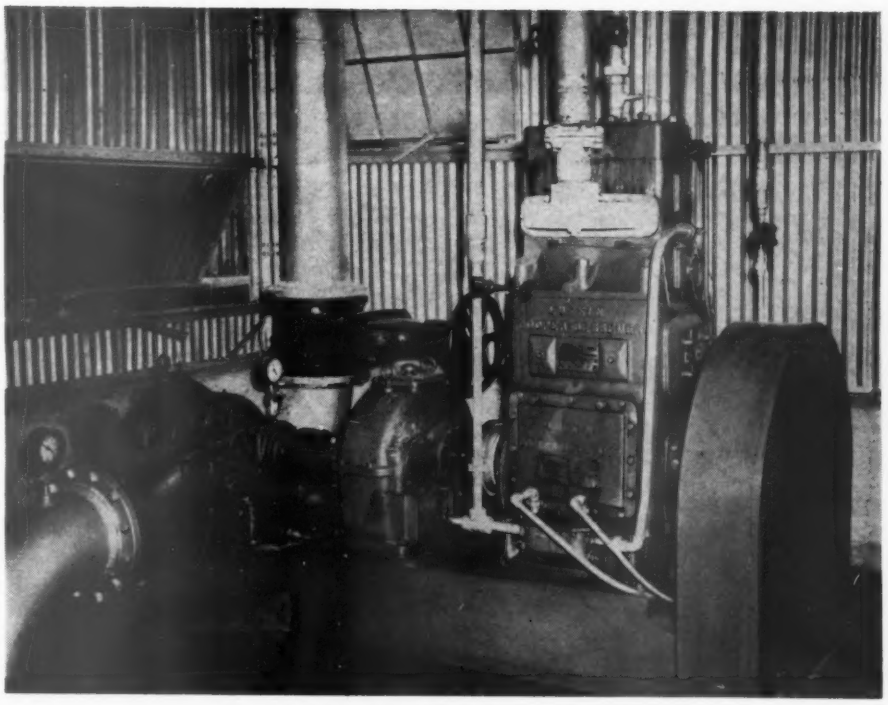
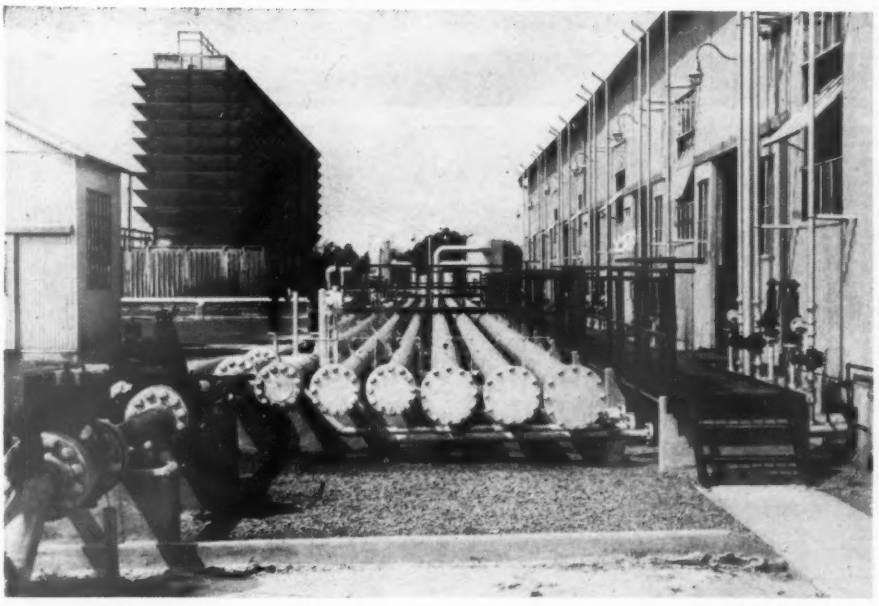
INSTRUMENTS CONTROL MODERN INDUSTRIES

sure from 2100 psi to 800 psi by a pressure reducing regulator and returned to the field for gas-lift purposes. The headers are so arranged that the entire 14,000,000 cu ft can be used for repressuring if the gas lift is reduced or eliminated entirely.

The rich oil is cold flashed from the high pressure absorber to 175 psi. Both vent gas and oil from the 175-psi flash tank go to the low pressure absorption system where they enter the cycle of the low pressure absorption plant. Operation of this plant is substantially the same as when it was constructed in 1939. One notable change has been made, however. When the plant originally was placed in operation the gasoline was charged from the low pressure accumulator to the gasoline stabilizer, whereas today this charge, as well as 12,000 gal a day of approximately 60-lb RVP products from the H. M. Harrell gasoline plant in the Bammel field, is pumped into the recompressor discharge line against a 240-psi discharge for coil blending purposes. This product finds its way into a 240-psi high pressure accumulator tank and from there is pressured directly into a 230-psi gasoline stabilizer on which is maintained a base temperature of 330 F. This change in procedure has increased production by approximately 600 gal per day on coil blending alone, and installation of the high pressure absorption has resulted in an increased production of 4000 gal per day substantially all of which is 100-lb LPG.

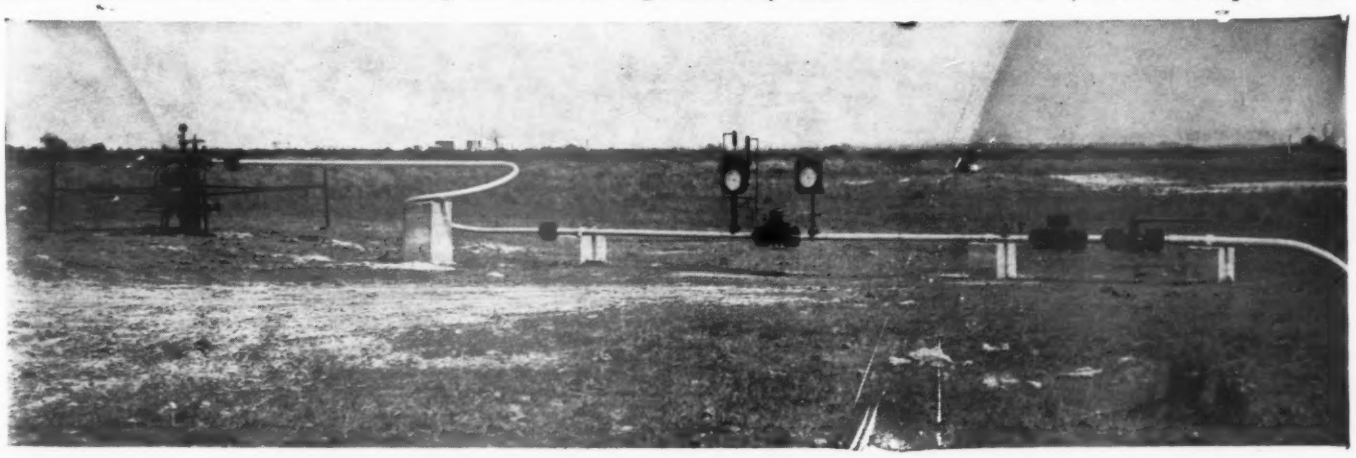
All operating companies in the field are participating in the pressure maintenance project. These companies are T. J. Ahern, Amerada Petroleum Corporation, A. W. Crosby, Gem Oil Company, C. N. Housh, Johnson and Johnson, Moran Corporation, Noble and Baker, E. W. Ogden, Haynes B. Ownby, Rancho Oil Company, S. W. Richardson, Showers and Moncrief, Sinclair Prairie Oil Company, Skelly Oil Company, Sohio Petroleum Company, Stanolind Oil and Gas Company, Union Producing Company, H. E. Williams and F. A. Gillespie and Sons, H. E. Williams and Lundy & Pyle, H. E. Williams, and Windsor Oil Company. The Fairbanks Field Operators Committee has been formed



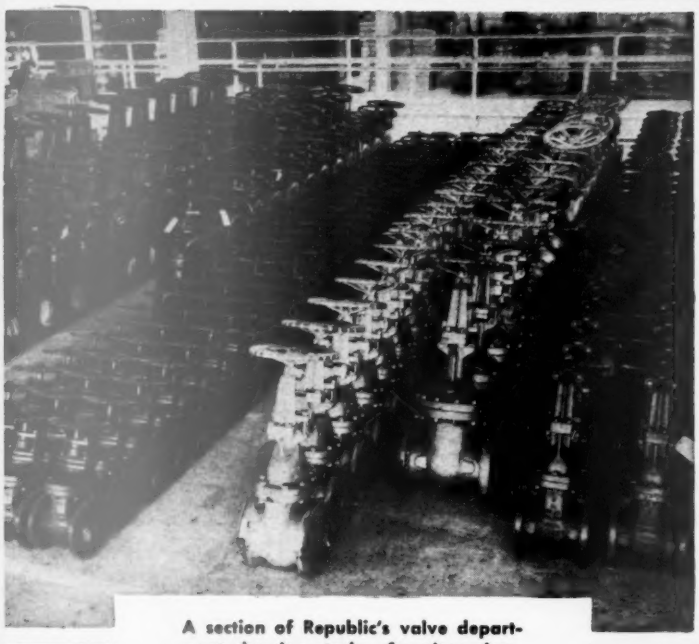


One of the cooling tower suction pumps driven by vertical gas engine is shown above. Below are gas suction and discharge headers. Cooling tower is in left background.

Residue gas is returned to the producing formation through three key wells. This is White No. 5, one of the input wells.



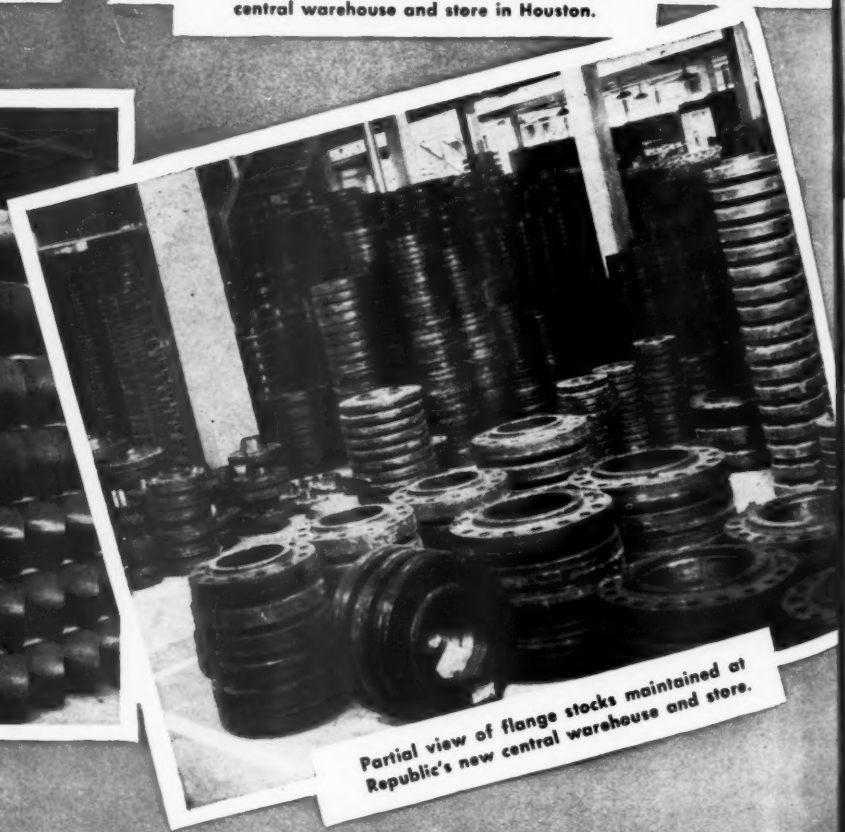
MODERN REFINER



A section of Republic's valve department showing stocks of various sizes.

Plug valve stocks at Republic's new central warehouse and store in Houston.

Republic's completely stocked welding fittings department.



Partial view of flange stocks maintained at Republic's new central warehouse and store.

REPUBLIC SALES AND SERVICE POINTS

ARKANSAS—El Dorado, Patmos; ILLINOIS—Chicago†, McLeansboro, Salem; INDIANA—Griffin; KANSAS—Ellinwood, Russell, Wichita†; LOUISIANA—Haynesville, Lake Charles†, Mamou, New Iberia, Rodessa, Shreveport*; MISSISSIPPI—Jackson; NEW MEXICO—Artesia, Hobbs; OKLAHOMA—Cement, Oklahoma City, Seminole, Tulsa†; TEXAS—Abilene, Alice, Big Spring, Borger, Columbus, Corpus Christi, Dallas†, Electra, Falfurrias, Fort Worth†, Hebbronville, Houston*, K-M-A, Kenedy, Kermit, Kilgore, Nocona, McAllen, Monahans, Odessa*, Olney, Pampa, San Antonio†, Sundown, Talco, Victoria, Wichita Falls*

*District offices and stores. †Sales Office.

ERY *Warehousing*

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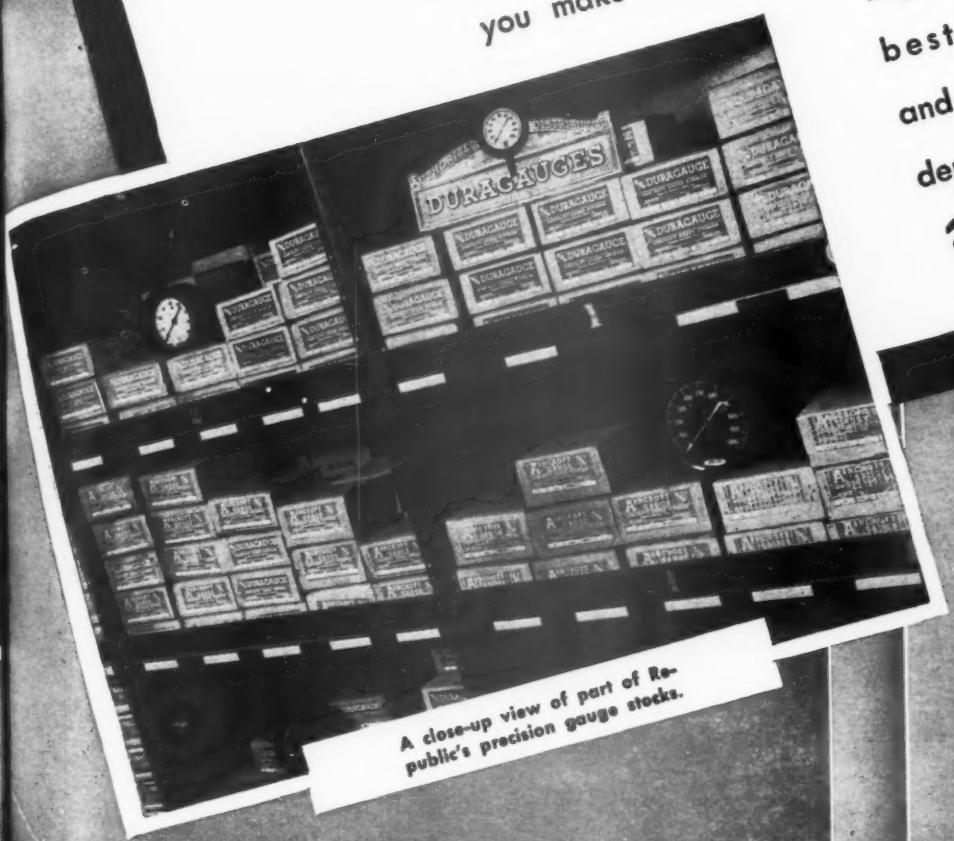
Makes your large inventory investments unnecessary —
Eliminates your costly accumulation of "dead" stocks —
Reduces your losses sustained from obsolescence —
Assures you proper stocks when and where they are needed —

● These are important advantages you enjoy when you make REPUBLIC your warehouse for refinery supplies. For everything best in refinery supplies and service you can depend on REPUBLIC. . . .

Your Supply Store



A close-up view of part of Republic's precision gauge stocks.

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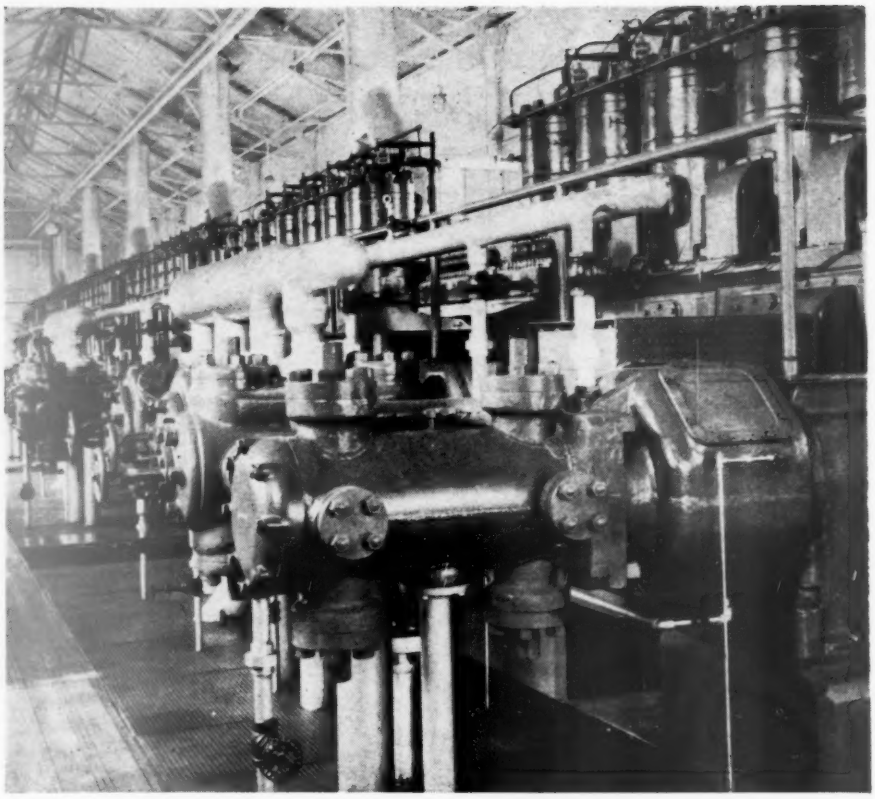

Six 600-hp angle type compressors receive gas from the field at a pressure of 39 psi, and compress it in three stages to a discharge of 2100 psi. Compressors are 2-cycle, right angle type and operate at 300 rpm.

by these companies and Joe Nalle is field engineer for the committee.

● **Description of equipment.** The six 600-hp compressors installed for pressure maintenance purposes are of the 2-cycle, right angle type and operate at a speed of 300 rpm. Compression is in three stages. Suction pressure on the first stage is 39 psi and discharge pressure is 140 psi. Second stage discharge pressure is at 550 psi and the third stage discharge at 2100 psi.

Each unit has clearance pockets for 1800, 2000, 2200, and 2500 psi discharge pressure. The compressor units each have one 10¼-in., one 7¾-in., and one 4¾-in. compressor cylinders. Air intake filters and coolers also form essential auxiliary equipment for the compressors.

Safety devices are provided that first sound an alarm then ground magnetos to shut down the units should the engines overspeed, water temperature become too high, oil pressure too low, or third stage gas pressure exceed 2500 psi.

The jacket water pump is driven from the flywheel of the engines by V-belts.

To take care of the added load, a 12-bay extension was made to the cooling tower, which is of the atmospheric type and designed with spring spray heads. Cooling tower suction pumps consist of two 12-in. by 14-in. horizontal split case, single stage, double suction, bronze fitted, ball bearing, centrifugal units

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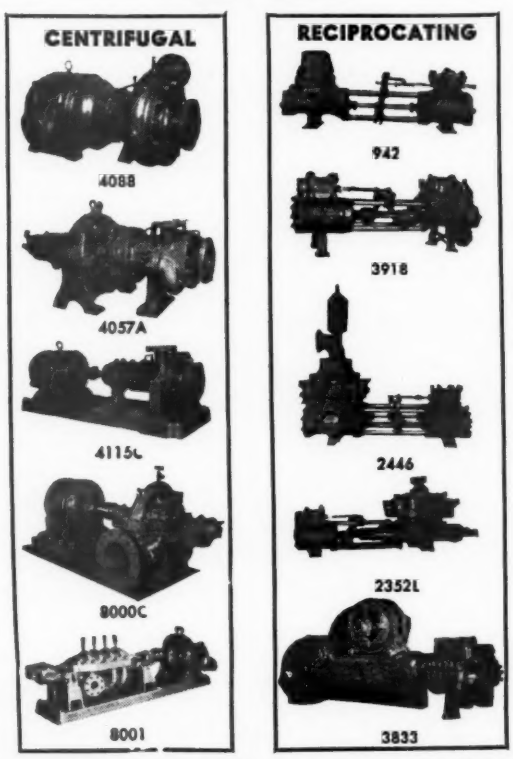
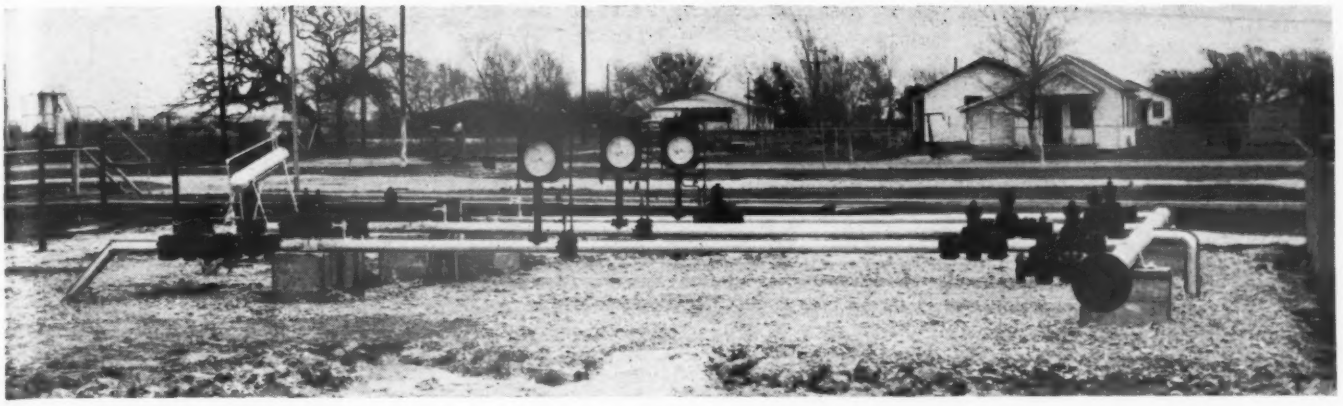


BRANCH OFFICES: NEW YORK HOUSTON



Part of the residue gas is used for gas lift purposes. Gas so utilized is about 4,000,000 cu ft a day, metered at this station.

having extended shafts and flexible couplings. They are driven by 7½-in. by 9-in. twin cylinder, 2-cycle, vertical gas engines connected through speed increasers. Operating at 1150 rpm, the pumping units deliver 3800 gpm each of 90-100 F water at a 54-ft water head.

The high pressure absorber is 3 ft ID by 54 ft high and contains 20 trays. Maximum working pressure is 594 psi.

The inlet scrubber is 3 ft diam by 8 ft high and is equipped with a control that will automatically ground magnetos and shut down the engines should the fluid level become too high. This control, however, operates only when the automatic liquid dump on the engine low stage intake scrubbers, which provides primary protection for the engines, is unable to handle any excessive liquid flow.

The second stage suction scrubber is 5 ft diam by 7 ft high and the second stage discharge scrubber is 3 ft diam by 7 ft high. Both scrubbers are equipped with continuous drains.

Two 30 in. diam by 6 ft starting air tanks maintain 200 psi constant starting air pressure.

Lean oil circulation is through a split system. The high pressure absorber pump, a simplex plunger type unit, takes suction from the existing discharge line of the low pressure system downstream from the lean oil coolers. A total of 560 gpm is circulated through the low pressure system and 66 gpm through the high pressure system.

● **Producing and injection wells.** The Fairbanks field has 270 producing wells upon which the Railroad Commission of Texas fixed an allowable of 7102 bbl a day in its last order. These wells are producing from the Fairbanks sand in the Yegua formation at a depth of 6830 ft. Residue gas is being returned to the formation through the tubing of the following wells: Foley No. 30, Silverberg No. 4, and White No. 5. As has been stated, injection is at a pressure of 2100 psi and at the rate of approximately 10,000,000 cu ft a day.

The pressure maintenance and high pressure absorption systems were designed and constructed by O. L. Olsen, contractor, of Houston, Texas. Henry J. Bourke is plant superintendent for Warren Petroleum Corporation and C. N. Delay is chief engineer. ★★★

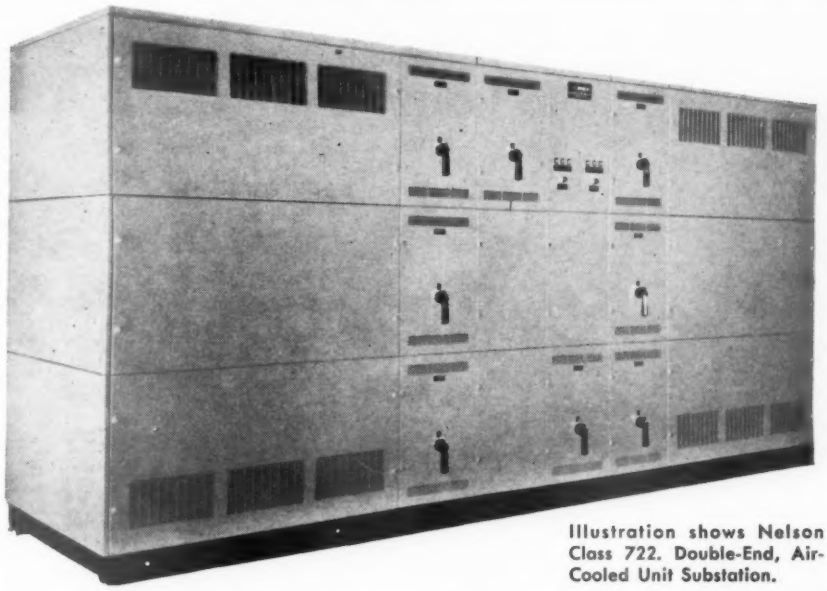


Illustration shows Nelson Class 722. Double-End, Air-Cooled Unit Substation.

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This new Unit Substation was recently built by us for a large refining company for installation in a power generating plant. Features of the unit include:

Indoor, dry-type transformers.

Tie breaker and two separately energized busses.

Disconnecting breaker to each transformer, permitting either transformer to feed total load; or permitting either transformer to carry half the load.

Drawout type breakers . . . Alarm circuit . . . Complete assembly at factory.

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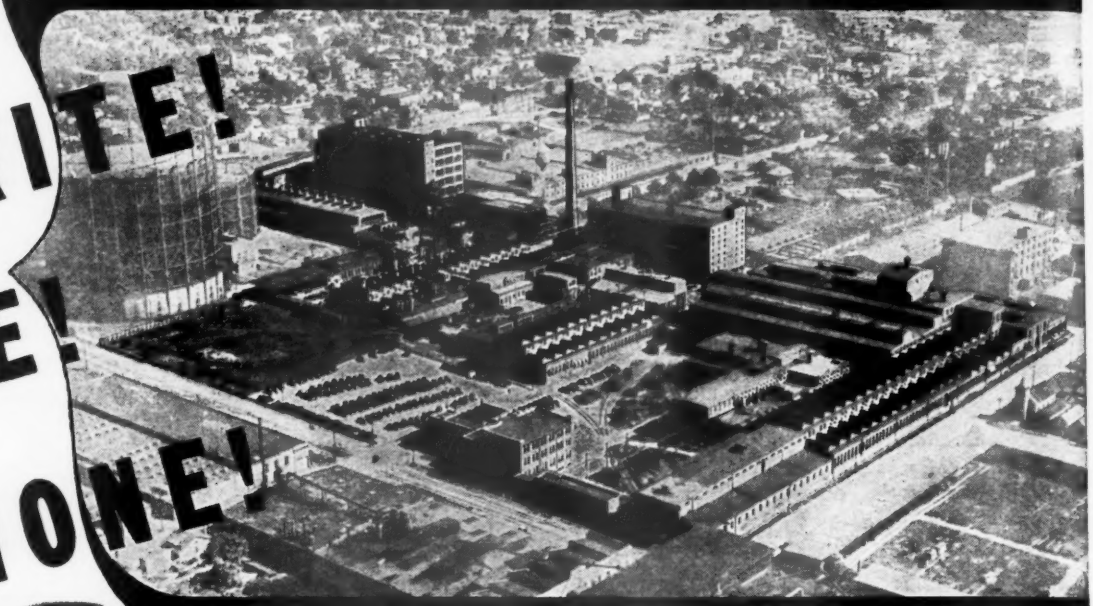

Air View of Henry Vogt Machine Co. Plant, Louisville, Ky.

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General view of the refinery at Whitehorse, Yukon, which was purchased by Imperial Oil Limited. Loaded piece by piece the plant was trucked almost a thousand miles to Dawson Creek and shipped from there to Edmonton by rail.

Northland refinery moves south

By GEORGE A. LAWRENCE, Imperial Oil Limited

PERHAPS it could only happen in the Yukon—the part of Canada's far northwest that rubs shoulders with Alaska—that a 7000-ton refinery would be established with parts from 2000 widely scattered suppliers in the United States and Canada.

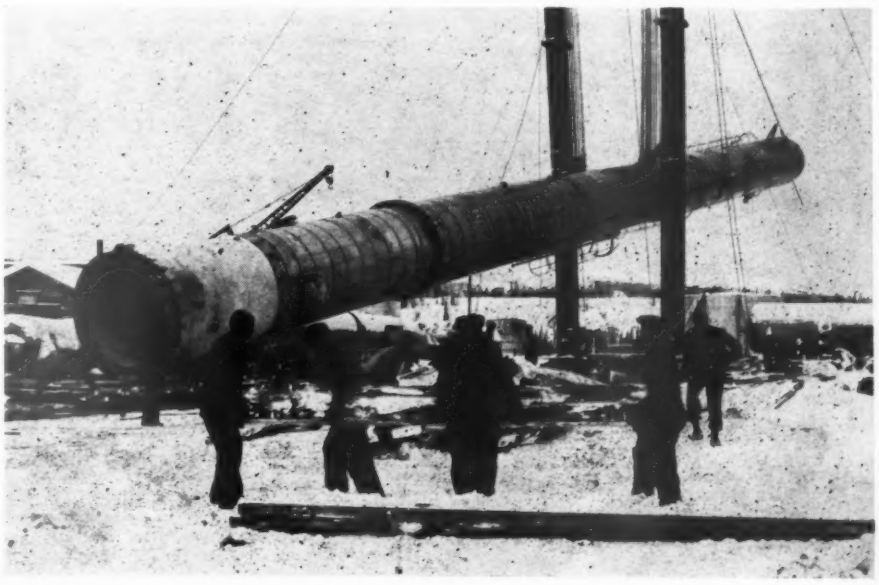
EXCLUSIVE

Equally unusual is the fact that a few years later the same plant—lock, stock and barrel—is on the move again and now has been transplanted to a new site more than 1300 miles away.

That in a nutshell is the history of Imperial Oil's growing refinery at Edmonton, Alberta. The migration is the result of the rapid development of Imperial's holdings in the Leduc oil field some 15 miles southwest of Edmonton.

As the world's most travelled refinery it is at last settling down; but it did not submit without a struggle. In seeming protest against leaving the Yukon for a permanent home in western Canada, it taxed man's ingenuity and tenacity to

A tower that is to be moved nears a horizontal position. Workmen built up trestles of timbers to provide a solid rest for the huge "tank."



the utmost in a winter-long campaign to complete the move.

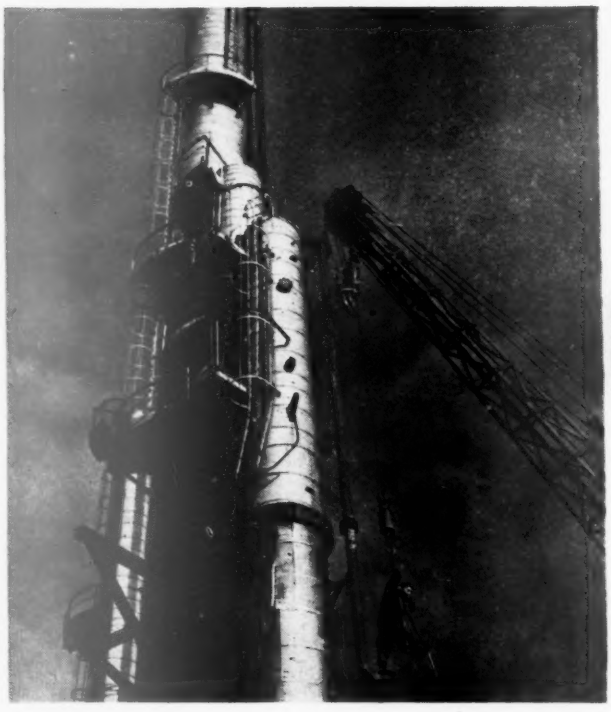
Originally the refinery was built by the U. S. in Whitehorse, Yukon Territory, to supply military demands when enemy forces threatened invasion of the North American continent through Alaska. After V-J Day it remained idle until last year when Leduc revealed itself as a high producer of urgently needed crude oil.

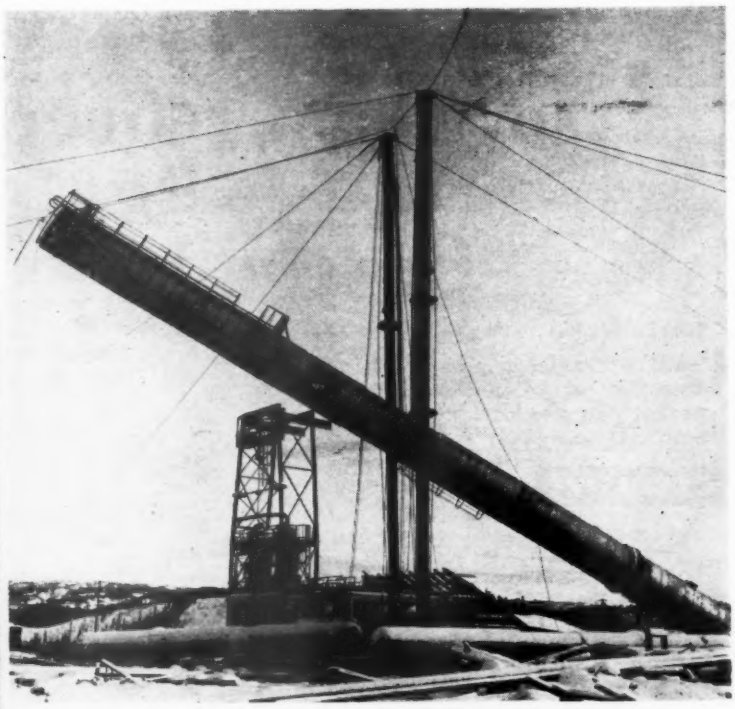
Imperial was faced with the need for a refinery close to Leduc, but the general shortage of building materials was a major problem. Imperial officials turned their eyes to Whitehorse for the solution.

Last summer Imperial purchased the refinery from U. S. war surplus goods for $1,000,000. The plan was to dismantle the plant at Whitehorse, haul it 919 miles by truck to Dawson Creek, B. C., via the Alaska Highway—another U. S. wartime emergency project—load it at Dawson Creek for shipment by rail about 400 miles to the new location on Edmonton's outskirts, and reassemble it there.

When the program is completed by the end of this year, the initial cost will have jumped to an estimated $7,300,000. There is no saving in cash outlay as against a new refinery but it will mean that operations can begin 18 months sooner. The first run of crude to be proc-

Deconstruction problems had to be met first. Everything was in readiness well in advance of actual moving operations. Towers were lowered intact and some transported in one piece. All projecting pieces like ladders, pipes, etc., were removed prior to the lowering of towers. Below, Canadian rigger, Joe Urbanowski, feels for footing after being hoisted by crane to tower. Riggers did much of the dismantling.





Above is another view of a tower being lowered. This shows more clearly the perfect alignment of poles and lengthening cable as the tower edges downward. Nearly all the super-structure was dismantled from the vessel well in advance and only the odd steel ladder and platform can be seen on the sides of the tank. About 75 ft of ground at both sides of the poles had been cleared to accommodate the tower after it reached the ground. All these units are needed for the plant when it is set up at Edmonton, Alberta, to process Leduc field crude oils.

IS YOUR SLIPPAGE SHOWING?

..Important question for users of reciprocating pumps and air or hydraulic cylinder mechanisms

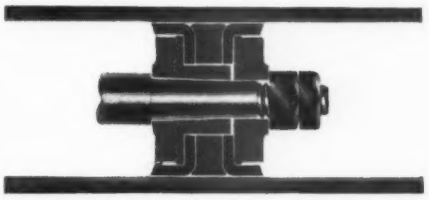
ILLUSTRATIONS at right show how Darcova Pumcups, in contrast to ordinary piston packing, virtually eliminate fluid slippage for the entire life of the packing. And, Pumcup life is many times that of ordinary packing.

By holding slippage to an absolute minimum, Pumcups permit reduced operating speeds, maintain high volumetric efficiency, prolong equipment life, save power, prevent wire-draw and uneven cylinder wear, and eliminate the need for frequent replacement shutdowns.

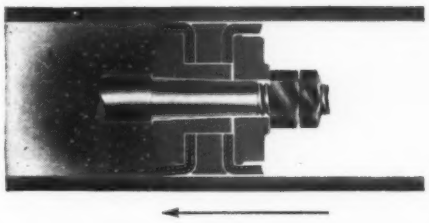
So if slippage is showing up in your operating and maintenance records . . . if replacement of packing is a too-frequent chore, that's your cue to switch to Darcova Pumcups.

For a free bulletin containing complete information, write, or use the coupon below.

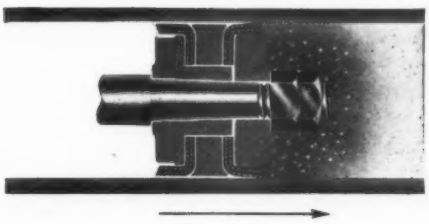
DIAGRAM OF PUMCUP ACTION GREATLY EXAGGERATED



NORMAL: BOTH PUMCUPS RELAXED



UNDER PRESSURE: PUMCUPS SEAL AGAINST CYLINDER DESPITE WEAR, MINIMIZING SLIPPAGE



Darcova Pumcups replace ordinary packing in reciprocating pumps and also in air or hydraulic control mechanisms. They are precision built of an exclusive, exceptionally durable composition material available in many textures for use with almost any fluid under a wide range of pressures and temperatures. Standard sizes range from ½ to 42 inches in diameter.

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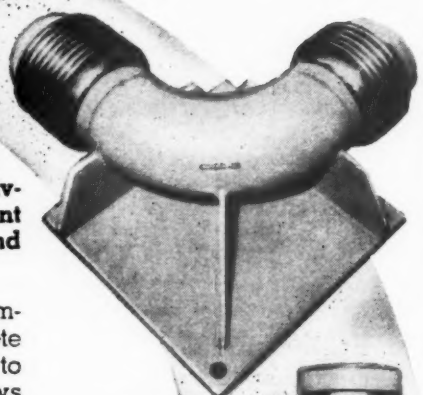
New expansion fittings save space, piping, and installation costs

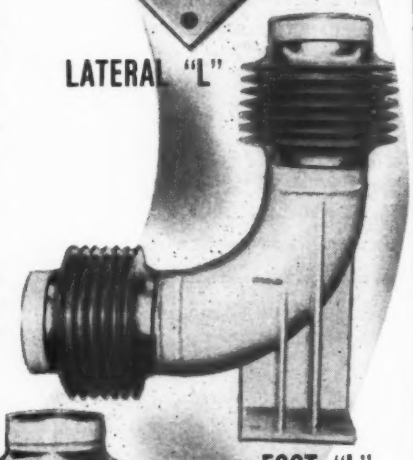
SIDE "T"



MagniLastic is first again with a new concept in simplified piping installation. Anchor base expansion joint fittings solve many plant layout problems involving limited space and movement due to changes in temperature and pressure.

As illustrated, a wide variety of combinations are possible, each complete with anchor base ready for bolting to floor, wall, or ceiling girder. Bellows are selected from standard MagniLastic catalog series to accommodate temperature, pressure and corrosive conditions. Number of diaphragms is variable to handle expansions encountered. Flanged or weld ends are optional.

LATERAL "L"



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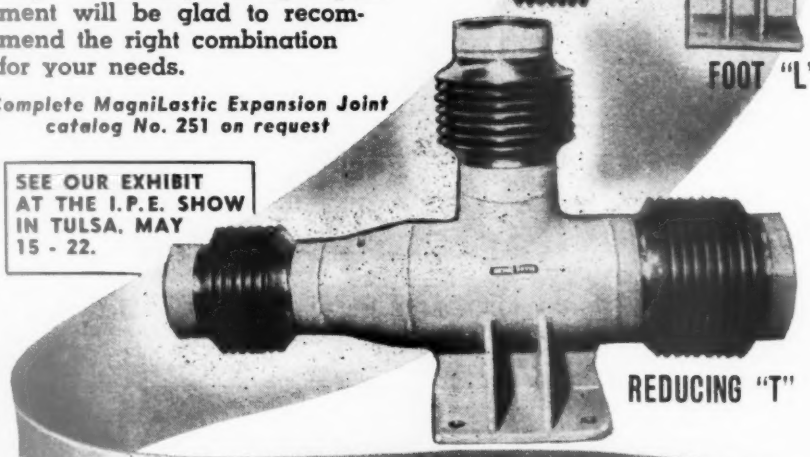

REDUCING "T"

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"THERE IS A MAGNILASTIC EXPANSION JOINT FOR EVERY PIPING NEED"

essed at the Edmonton refinery is expected to take place in July.

For the moving assignment, Imperial completed a contract with W. M. Barnes Company, Los Angeles engineers and contractors. The firm not only possessed the necessary equipment for the job but they were ready to start immediately.

Early in the fall of 1947 this firm had opened offices in Whitehorse, rigging crews had made a start on dismantling, eight big diesel trucks and trailers had started hauls on the Alaska Highway.

The whole operation followed a carefully planned pattern worked out in large part by the company's engineers along with the contractors. While the refinery disappeared piece by piece at Whitehorse it began to take form 1300 hazardous miles to the south. And in between some of the biggest motor vehicles operating anywhere in the world drove night and day on the 919 mile stretch of the Alaska highway to keep the pattern developing as plotted.

The Alaska Highway is kept in top condition, winter and summer, by Canadian Army engineers, but that does not make it an ordinary road. It winds through steep canyons, swamps, and muskeg, crosses scores of swift streams. Many of its hills are long and tough.

For that reason the biggest loads hauled by the usual truck power unit were aided over the toughest stretches by a pusher unit. This pusher was a truck tractor equipped for driving behind the loads to provide extra shoves when needed—which was often.

The trucks equal any standard model in the world in size and load capacity. They weigh almost 20 tons even when empty. The largest have 21 forward speeds and the dashboard resembles the instrument panel of a heavy aircraft. They are equipped with a box-like sleeping compartment behind the cab. In this way one of the two-men crews kept the road-giant rolling while the other slept.

Guiding these automotive dreadnaughts on the best of modern highways requires special skill. Controlling them on the sharp curves and mountain slopes of the graveled Alaska highway required that same skill plus stamina and daring in full measure.

It is a tribute to the transportation group that the whole refinery reached Edmonton safely by the spring of 1948. An unbelievably mild winter throughout the Yukon was of great help to the dismantling crews, but it was not particularly welcomed by the drivers. Scant snowfalls, followed by quick thaws, put an icy surface on the highway many times.

For days at a stretch the highway was too treacherous for any truck movement. By Christmas it was evident some additional transportation would be required to complete the hauls on schedule.

As a result the Canadian Pacific Steamships' coastwise freighter "Nootka" came into the picture. This vessel took on two full cargoes of refinery equipment in Skagway, Alaska, during January and February. These shipments totaled more than 2000 tons and were

delivered to Vancouver B. C., for shipment by rail to Edmonton and reached the refinery site by mid-March.

Pipe, sheet steel, and smaller items shipped on the "Nootka" first had to be transported by rail from Whitehorse to Skagway. This involved the use of the famous and colorful White Pass and Yukon railroad, a narrow gauge line that runs over 110 miles of the most spectacular and rugged mountain country to be found anywhere.

About 30 of the heaviest truck loads could not be moved until February and March after a full winter had frozen the roadbed solidly. Some of these loads involved huge vessels and towers weighing 40 to 50 tons each. Possibility of damage to the roadbed made their earlier movement impossible.

At one stage engineers in charge of the job came face to face with a special problem. A 3000-ft wooden bridge was not considered strong enough to carry the loads made up of the heaviest equipment. The bridge was 115 miles south of Whitehorse where the highway makes a jump across the arm of Teslin Lake. The engineers went into a huddle and came up with a unique solution—a bridge of ice.

Preparations for the ice bridge were made but nature interfered to halt the project. Mild weather prevailed over a long period just when cold was needed for the ice, so the scheme was abandoned. This meant that the loads had to be reduced accordingly.

Despite the many difficulties there were few real breaks in the steady flow of equipment into Edmonton. The whole project followed the carefully mapped pattern.

At Edmonton work crews (there were 400 men on the job in February) kept fitting the pieces together and the refinery took shape again. By mid-winter the crude unit was well on its way to reconstruction and the first tower was pushed up soon after Christmas.

At Whitehorse, dismantling of one large unit created special excitement. It was the lowering of the 146-ft deisobutanizer, a vessel used in processing of aviation gasoline and which towered over all others in the refinery. It had become something of a landmark to residents in the Yukon community. Many turned out to see it lowered and cheer the riggers as the "big can" reached the ground.

To lower this tower welders had put together two "gin poles" from old bridge

Adds to Elk Hills

Secretary of Interior Krug has set aside 2480 acres of federal land adjoining the Elk Hills Naval Oil Reserve in California for Navy exploration.

The action permits the Navy to incorporate temporarily the Kern County acreage in its Petroleum Reserve No. 1 for the Navy's exclusive use, according to report.

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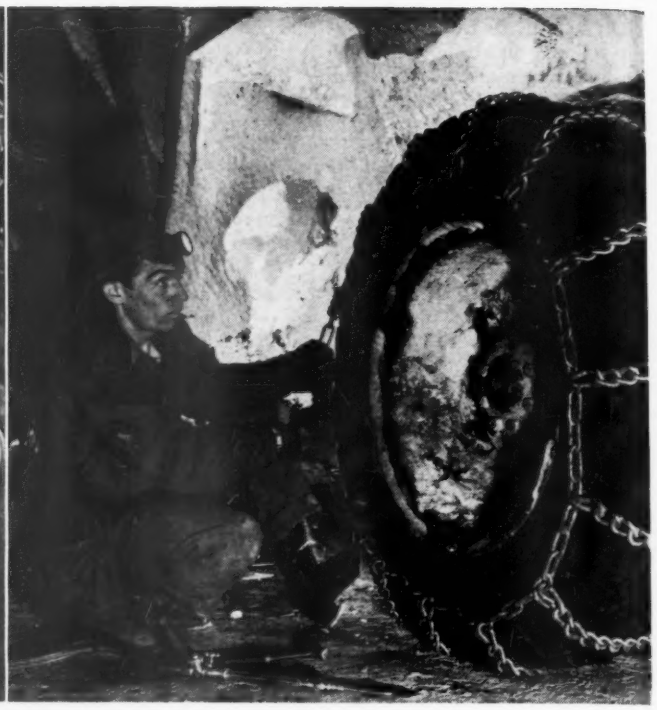


The huge Kenworth trucks, said to be among largest in the world, carried the refinery equipment from Whitehorse to Dawson Creek. Value of one truck and trailer is $35,000. Above is a view of the elaborate instrument panel of one of the trucks, which is similar to that of an airplane. The truck has 21 speeds forward. Above right shows a truck at the repair station maintained by company in charge of Whitehorse refinery operation at Muncho on the Alaska Highway. Driver Smoky Gray adjusts chains on the huge tires of his truck. Below is one of the trucks running along the snow-covered Alaska Highway. The big moving project is expected to save about 18 months time in getting a refinery into operation to handle crude oil from the Leduc field.

girders loaned by the Canadian Army. These 96-ft poles were erected on either side and cable slings were linked from the tops to lugs on two sides of the tower. Winches made the initial upward lift of the tower between the poles, and as the base was hauled away at a right angle the cables lowered it gently into a horizontal position.

Much of the dismantling was limited to hours of good visibility for in that part of the world there is little daylight during mid-winter months. Steel framework of all main buildngs was cut by torch. Each piece was carefully labeled and at the same time numerous photographs were taken of sections of the refinery. At Edmonton, refinery welders and construction men followed the numbering system and the photographs in rebuilding the units.

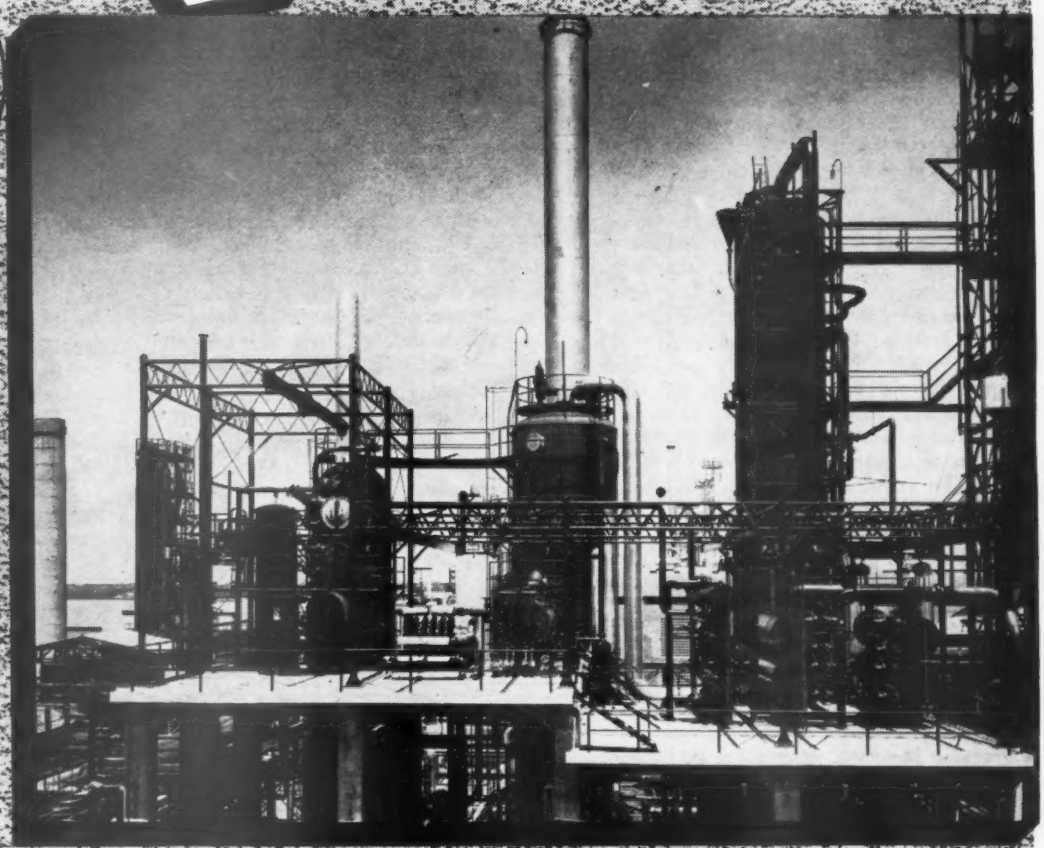
By March 1 all but the tag ends of the dismantling were completed. By the time this magazine goes to press the last truckload of equipment will have reached Edmonton. Truckers will have driven an estimated 400,000 miles in transporting Imperial's latest refinery.

Throughout the coming summer reconstruction at Edmonton will be pushed as rapidly as possible. The mild weather that retarded part of the undertaking in the north helped workers in Edmonton who were preparing foundations and laying water and sewer systems at the new site. Much of their work has been completed ahead of schedule.

The Alaska Highway, snaking its way through the northern wilderness, gave a big assist in the undertaking. It is one joint U. S.-Canada wartime project that paid off in a peacetime role of importance to all of Canada. Without it Imperial's new refinery would not be so near realization and the increased production of urgently needed petroleum products from Leduc field would be delayed many months. ★★★

TULSA TYPE

BUILT Right



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P 762.2

High pressure power station at Whiting

By D. A. MONRO and A. T. MILBROOK, Standard Oil Company (Indiana)

● **Introduction.** One of the earliest industrial applications of the by-product generation of power by means of the high back pressure cycle was made by the Standard Oil Company (Indiana) at its Whiting, Indiana, refinery when it placed in operation in 1928 a power station operating at initial steam conditions of 400 psi* 650 F total temperature. The exhaust from the turbo-generators was distributed to the refinery for steam power and process at a pressure of approximately 100 psi and a total temperature of 450 F. The quantity of steam required by the refinery was sufficient to produce considerably more by-product power than was needed at the time. The trend in refinery operation, however, was in the direction of replacement of uneconomical steam drives with motor drives utilizing inexpensive by-product electrical energy. Changes in process design were responsible for further reductions in the demand for steam per barrel of crude oil put through the refinery. Consequently, the tendency was for the steam demand to remain static or to increase at a low rate while the demand for electrical energy increased at a high rate. The surplus of power, therefore, was consumed rapidly and eventually it became apparent that the total amount of by-product power available with the existing back pressure cycle would be insufficient to supply the ultimate demand for power and that alternative methods of producing power economically must be devised.

Shortly before this country entered World War II, when it was seen that an expansion in power generating facilities was imperative, an engineering study of the problem was begun. Two fairly obvious solutions presented themselves, namely, the installation of condensing turbo-generators operating at an initial pressure of 400 psi, or the installation of units to top the existing cycle with another in which the turbines would exhaust at 400 psi with throttle conditions sufficiently higher to generate enough power to satisfy the anticipated demand for some time in the future.

If the 400 psi condensing cycle were adopted, steam, in addition to that required by the refinery for process, power, and heating, would have to be produced for power generation alone at the rate of approximately 11 lb per kw with approximately 70 per cent of the heat lost in the condenser. However, with a topping cycle, additional power could be obtained with no increase in steam production and with only a relatively small increase in fuel consumption due to the increase in steam pressure. Thus, with a topping cycle operating at initial conditions at the turbine throttle of 1250 psi 900 F an additional kilowatt could be generated for each 34 lb of steam delivered to the refinery at 400 psi, or for each 1000 lb of steam produced at 1250 psi and used by the refinery at 400 psi approximately 30 kw of by-product power are made available. Similarly, for each 1000 lb of 400 psi steam used at 100 psi, 25 kw are made available and for each 1000 lb of 100 psi steam that is reduced to 10 psi the power available is 20 kw. Thus, the total by-product power made available with the 1250 psi topping pressure per 1000 lb of process steam is as follows: For steam used at 400 psi—30 kw; for steam used at 100 psi—55 kw; and for steam used at 10 psi—75 kw. The increase in fuel consumption caused by the generation of steam at the topping pressure amounts to slightly less than 10 per cent over the fuel required for a pressure of 400 psi.

As the differential between the initial and exhaust pressures of the topping turbine decreases the availability of by-product power from the topping cycle also decreases rapidly. The power available per 1000 lb of steam for topping steam conditions of 900 psi 825 F is only 70 per cent of that obtained when operating at 1250 psi 900 F. The indications at Whiting were that the increased demand for power would be so large that adoption of the higher pressure was warranted not only from an economic standpoint but was necessary in order to supply the predicted demand.

The topping cycle, however, presented certain problems that required careful investigation before a final decision could be made. Foremost of these problems was that of treating practically 100 per cent of the feedwater to be supplied to a boiler operating at pressures of 900 to 1500 psi or even higher. The supply of available condensate from refinery process operations was relatively small in amount, likely to be contaminated, and so widely distributed that its collection and return to the boilers was not economic. The first phase of the engineering study, therefore, was investigation of the practicability of operating boilers at high pressures with 100 per cent makeup. The successful use of raw Lake Michigan or Mississippi or Missouri River water as boiler feed at pressures up to 600 psi had already been established in the company's own experience at several of its refineries. This water had previously been used as cooling water in process units and was available in sufficient quantities at temperatures varying from 120 F to 180 F to make its return to the power station and its chemical treatment very attractive compared to any other method of procuring suitable boiler feedwater. The engineering study had proceeded to the point where it was apparent that such operation was likely to be quite feasible, when the outbreak of the war and the inability to obtain the critical turbo-generators and high pressure boilers pigeonholed the project.

The refinery expansion resulting from the unusual wartime demand for petroleum products, including aviation gasoline and toluene, made it necessary to construct a steam generating plant with a total capacity of 1,000,000 lb per hr, designed for a pressure of 400 psi. The boilers selected for this plant were constructed with a large number of relatively small tubes in the convection section. Based on previous experience with feeding phosphate directly into the boilers it was anticipated that trouble would be encountered with sludge formation in regions where circulation might be sluggish. It was decided to reduce the hardness of the boiler feedwater to the lowest value possible and to accomplish this by the use of a two-stage hot process treating system in which the customary lime-soda treatment was supplemented by phosphate treatment in an external sedimentation tank followed by filtration and deaeration. As the water was treated at a pressure of about 10 psi and the deaerator operated at this pressure also, there was no appreciable increase in temperature in the deaerator and sludge formation there was negligible. No further heating of the feedwater occurred ahead of the boilers. This system of water treatment has been in operation since July, 1943, with very satisfactory results and has provided a valuable background of experience in preparation for the operation of a similar system to supply feedwater for the higher pressure boilers in the new station.

Under wartime conditions emphasis was placed on supplying the demand of the refinery for steam and power with the minimum amount of equipment and materials rather than an operating economy, consequently a return to normal conditions, together with contemplated postwar expansion of the refinery, made it necessary to review the requirements for steam and power and resume the analysis of the best and most economical means of supplying the greatly increased demands. Other cycles than topping and condensing were investigated but were discarded as unsuitable to the particular needs of the refinery. Because of the large demand for steam, the topping cycle was still the most at-

*Throughout article pressures are gauge pressure.

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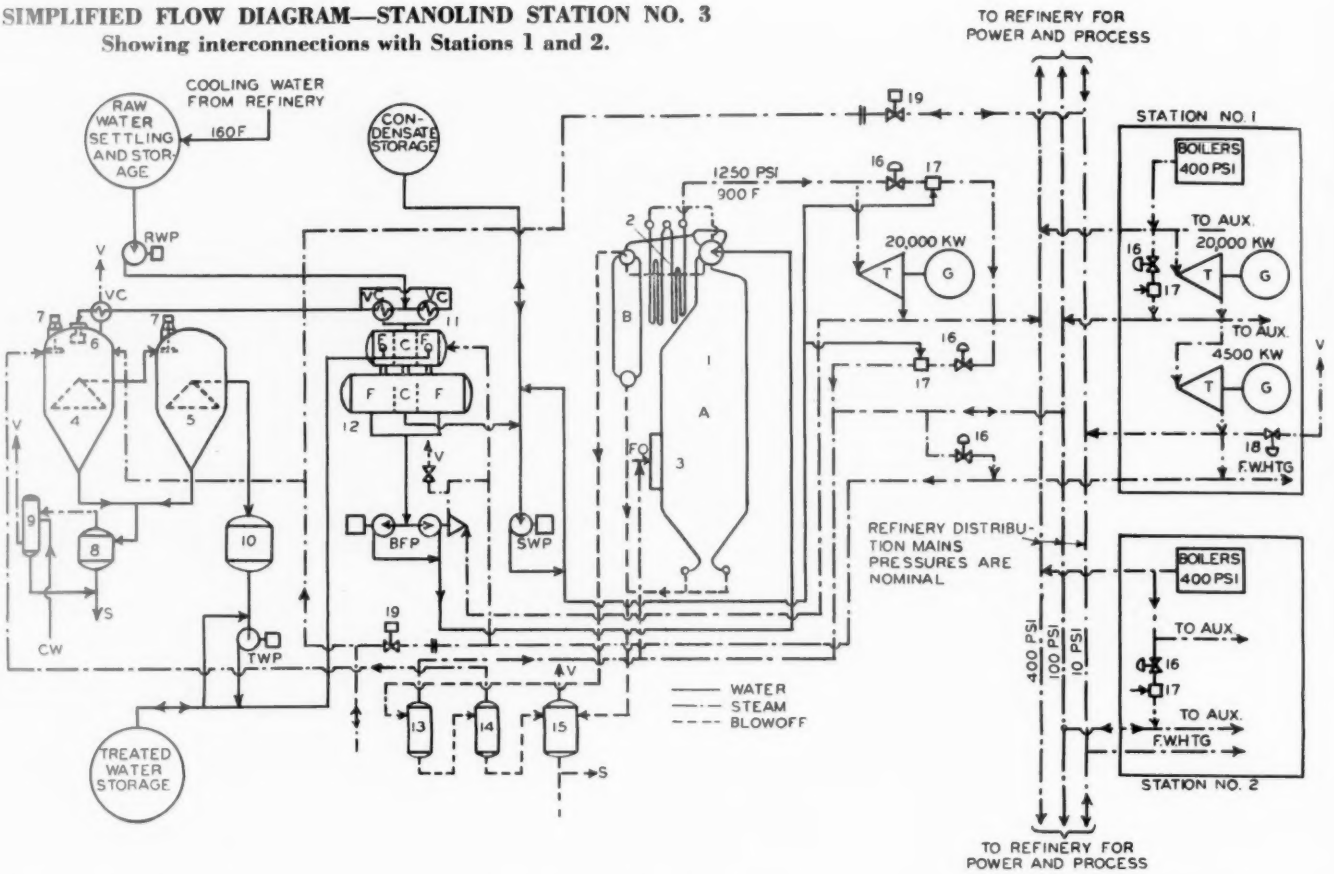
SIMPLIFIED FLOW DIAGRAM—STANOLIND STATION NO. 3
Showing interconnections with Stations 1 and 2.



RWP—RAW WATER PUMPS
TWP—TREATED WATER PUMPS
BFP—BOILER FEED PUMPS
SWP—DESUP. SPRAY PUMPS
V—VENT TO ATMOSPHERE
VC—VENT CONDENSER
S—WASTE TO SEWER
T—TURBINE
G—GENERATOR
FO—FUEL OIL CW—COOLING WATER
FW. HTG—FEED WATER HEATING

1—STEAM GENERATING UNIT
A—PRIMARY SECTION
B—SECONDARY SECTION
2—SUPERHEATER
3—BURNERS
4—LIME-SODA SEDIMENTATION TANK
5—PHOSPHATE SEDIMENTATION TANK
6—HEATER
7—AGITATOR
8—SLUDGE BLOWOFF TANK

9—SLUDGE B.O. TANK VENT COND.
10—FILTERS
11—DEAERATING HEATER
12—DEAERATED STORAGE
F—BLR FEED. C—CONDENSATE
13—CONT. B.D. FLASH TANK—100 PSI
14—CONT. B.D. FLASH TANK—10 PSI
15—INT. BLOWOFF TANK
16—PESS. REDUCING VALVES
17—DESUPERHEATERS
18—BACK PRESS. REGULATOR
19—MOTOR OPER. CONTROL VALVES

tractive from the economic standpoint.

Consultation with boiler and turbine manufacturers led to the conclusion that the turbine throttle pressure and temperature should be kept within the range for which designs were well established. The topping turbine exhaust conditions of 400 psi 650 F were established by the pressure of the existing boiler installation. Utilizing performance data applying to topping turbines of the size, type, and efficiency available and suitable for the requirements, exhaust conditions of 400 psi 650 F at full load would be obtained with the following approximate steam conditions at the turbine throttle: 900 psi 825 F, 1250 psi 900 F, 1385 psi 925 F, 1525 psi 950 F, and 1850 psi 1000 F. Higher temperatures could be used at the lower throttle pressure by resorting to a thoroughfare desuperheater in the exhaust. The lower pressure was discarded because it did not make sufficient power available to satisfy the future demands. The highest pressure and temperature condition was not given consideration because at that time equipment to utilize 1000 F had not been sufficiently developed on a commercial scale. Analyses of the range from 1250 psi to 1525 psi indicated that the economic advantage in going to a pressure above 1250 psi was not sufficient to warrant its adoption.

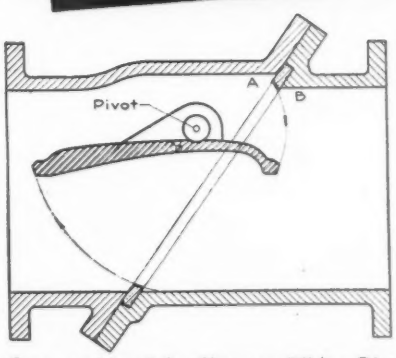
In the interval that had elapsed since the previous study had been dropped considerably more experience had been gained in the use of 100 per cent makeup in high pressure boilers. The boilers operating on the 100 per cent makeup in the 1200-1500 psi range, however, were using zeolite treatment starting with cold water, and where the ordinary hot process system was in use the boiler pressure was in the 900 psi range. Certain installations operating at 1200 psi with fairly high makeup were experiencing trouble with silica scale in the turbines and increasing attention was being called to the problem of silica in boiler water and steam, even in plants where the amount of makeup was very small.

The National Aluminate Corporation had been consulted from time to time in connection with this investigation and had expressed confidence that a boiler could be operated successfully at pressures up to 1500 psi with 100 per cent makeup using Lake Michigan water treated in a hot process softener. They were therefore retained to make further studies of the character of boiler scale that could be expected with the type of water treatment in use at Whiting in the pressure range of 1000 to 1500 psi. This work was done on a small pilot boiler and the results have been reported elsewhere.[1] It was concluded from this study that the nature of the deposits that might be experienced would not constitute a serious hazard and that operation under the conditions being considered was perfectly safe. Following this a further investigation was made on a commercial scale of the extent to which the silica content of the boiler feed could be reduced in a hot process lime-soda softener by the use of dolomitic lime and magnesium oxide. This work was also done by National Aluminate Corporation and the results indicated that silica leaving the softener could be reduced to less than 1 ppm without excessive chemical costs and that, with slight improvements in the design of the equipment and the employment of sludge recirculation, and careful control of the process, it would be possible to reduce the silica content to considerably less than 1 ppm.

As a result of the economic studies and experimental work on water treating methods it was decided to proceed

[1] "Experimental Studies of Boiler Scale at 1500 Psi," by J. A. Holmes and C. Jacklin, *Proceedings* of Sixth Annual Water Conference, Pittsburgh, Pennsylvania, October 22-23, 1945.

CHAPMAN TILTING DISC CHECK VALVES are designed to PREVENT SLAMMING



Cross-section of the Chapman Tilting Disc Check Valve illustrating the way that the balanced disc is supported on the pivot, with arrows showing the travel of the disc. A feature of the design is that the disc seat lifts away from the body seat when opening, and drops into contact when closing, with no sliding or wearing of the seats.

Specially designed to prevent slamming and its consequent jarring of pipe lines, Chapman Tilting Disc Check Valves consistently cut maintenance costs. Because of the cushioning effect of the stream against the short flap of the balanced disc, they close quietly without setting up destructive pipe-line stresses.

Head losses are reduced as much as 65% to 80% over those experienced with conventional type check valves because of the design of the balanced disc. And when installed on pump discharge lines, they not only make possible increased pipe-line capacity but also effect substantial power savings.

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with the design of a station using a two-stage hot process treatment, with turbines designed for throttle conditions of 1250 psi 900 F, and steam generators designed for 1350 psi at the superheater outlet. These decisions were reached by the company's engineers in collaboration with Prof. F. G. Straub of the University of Illinois and the National Aluminate Corporation.

Design of the station was begun by Stone and Webster Engineering Corporation in June, 1945. Initial operation is expected to begin in spring of 1948.

The new station, which is referred to as Stanolind Station No. 3, has been located adjacent to Station No. 1 to centralize utility operation, to permit use of existing coal car storage and unloading facilities in the future, to reduce the length of interconnecting lines between the two stations to a minimum, and to utilize the exsting raw water collecting and storage facilities. To provide space for the new installation it was necessary to dismantle existing refinery units and to reroute a large number of lines serving the area involved. For this reason actual construction of the new station was not begun until the summer of 1946.

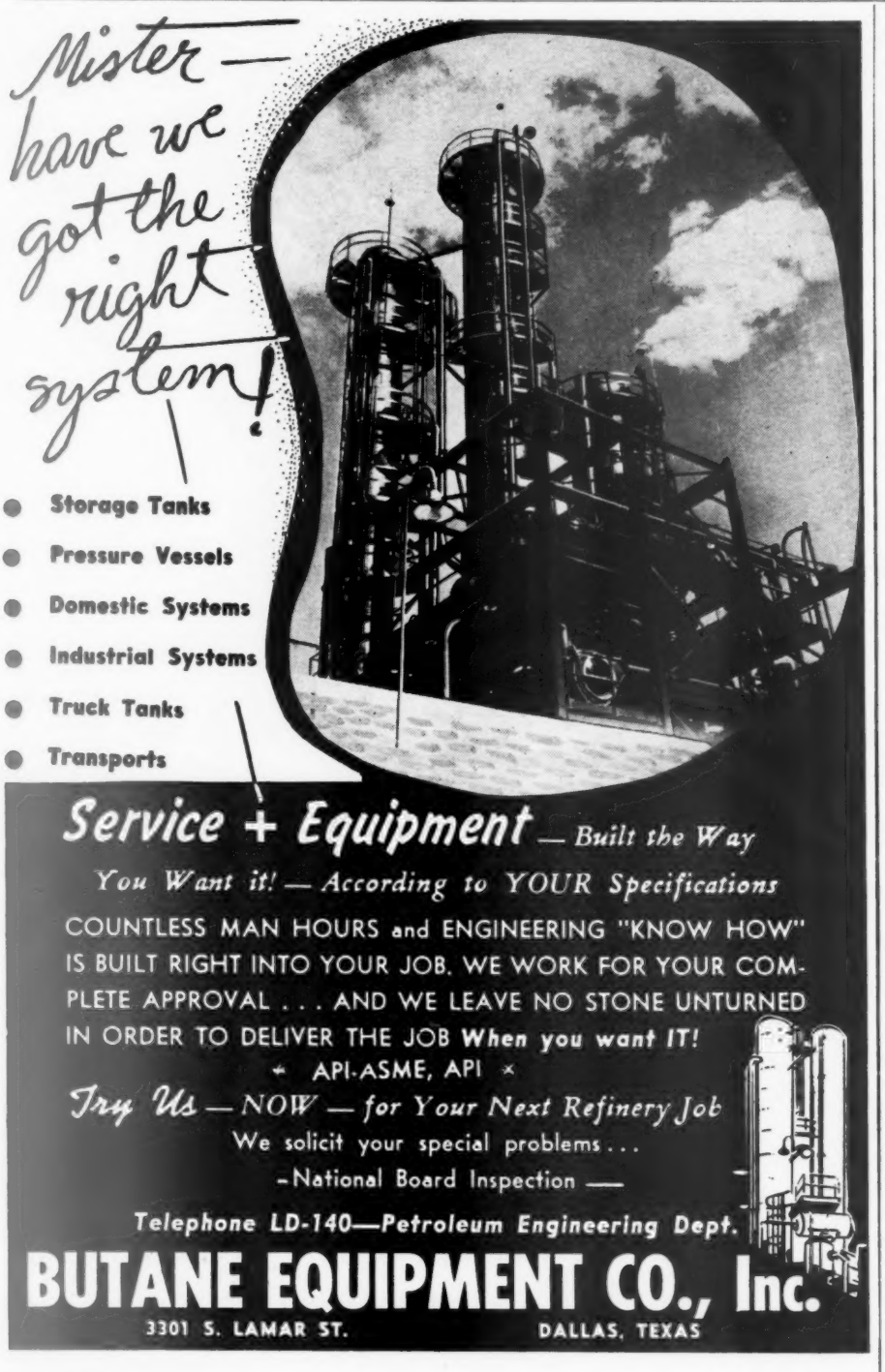
Emphasis in the design and layout of the power station has been placed on minimum overall cost of steam and power, on continuity of service, and on dependability.

● **Steam generating unit.** One of the most interesting features of the new installation at Whiting is the dual circulation steam generating unit designed by Foster Wheeler Corporation to operate at high pressure on essentially 100 per cent make up with minimum blowdown. Although the reduction in blowdown made this unit attractive from an economic standpoint, it was the ability to operate with low boiler water concentration in the highly heated tubes and resulant low silica contamination in the steam that greatly influenced its selection for this installation. A considerable portion of the steam supplied to the refinery by the 1250-psi topping turbines will pass through a large number of steam turbines in the refinery operating at throttle pressures of 400 psi and 100 psi driving pumps, blowers, fans, etc., both in regular and standby service. As this is the range of pressures and temperatures in which silica deposits are most likely to occur, it will be apparent that the utmost precautions to reduce silica contamination to an absolute minimum are warranted.

The unit resembles a conventional three drum boiler but is actually divided into two separate heat absorbing sections each with its own independent circulation system. One of the sections, referred to as the primary, or high duty section, comprises the strongly heated radiant heat absorbing furnace. The secondary, or low duty, section consists of the convection section of the boiler in which the rate of heat absorption is relatively low.

The Whiting units are designed for a continuous output of 300,000 lb per hr at a pressure of 1350 psi at the superheater outlet and a total temperature of 900 F. The units are designed for firing with pulverized coal, fuel oil, and refinery gas. Initially only the two last named fuels will be fired. The furnace is designed for an unusually low heat release, which is a distinct advantage both from the standpoint of high make-up and coal burning.

The boiler feed is introduced at a temperature of 240 F into the 72-in. diam main drum of the primary section where it is heated by direct contact with the steam produced in the secondary section. The water then passes into the main body of the drum from which it is carried through multiple pipes distributed along the drum to two large external downcomers and thence to the water wall headers at the bottom of the furnace. Independent circuits are provided for each of the corner tubes and for the pairs of tubes adjacent to the corner tubes to insure positive circulation in the portions of the water walls that have relatively low rates of heat absorption. All flow in the furnace wall tubes is upward. The mixture of steam and water leaving the wall tubes passes through washing and separating compartments in the primary drum. The most highly concentrated water in this drum is then carried by means of a series of external circulating tubes to the upper drum of the secondary section and is the feed for this section and constitutes the continuous blowdown from the primary section, and because of its magnitude with relation to the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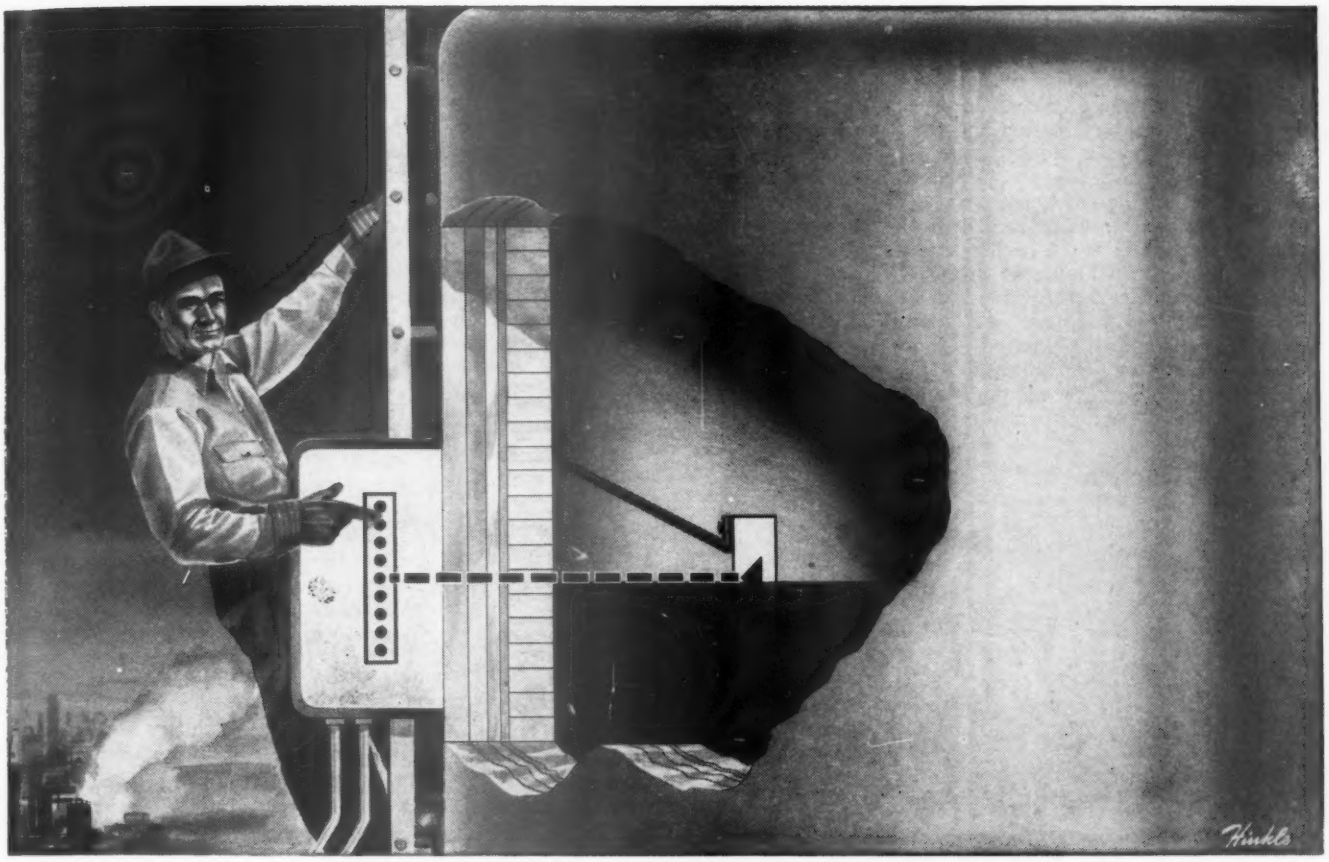

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A GAGETRON AT WORK

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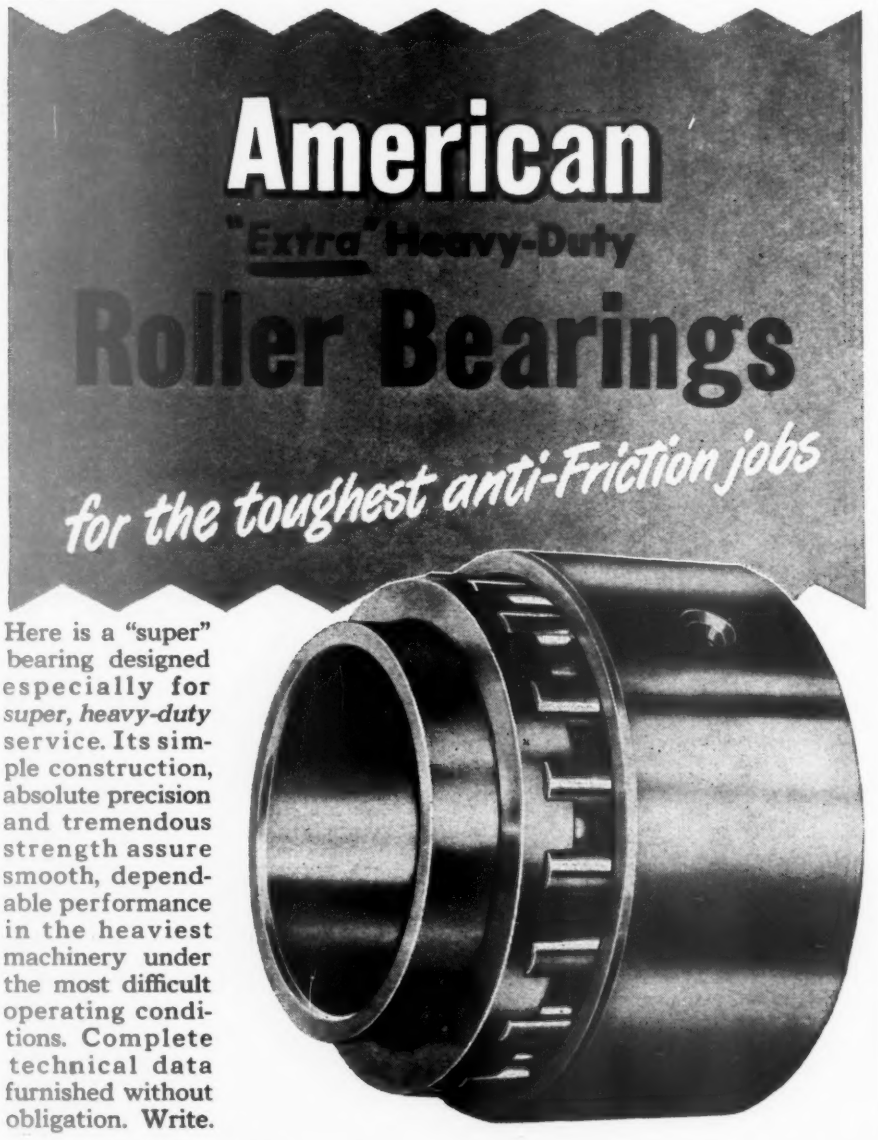
steam ouput of the unit, results in a low boiler water concentration in the primary section. The feed to the secondary section is the sum of the steam produced in the secondary section and the blowdown from the unit. Due to the relatively low rate of heat input to the convection bank the boiler water concentration which can be maintained in the secondary section is much higher than that which is permissible in the furnace tubes. Consequently, the blowdown rate from the unit and resultant heat loss can be greatly reduced compared to the blowdown that would be required in a conventional unit. Not only is the blowdown loss greatly reduced but the danger of furnace tube failures is minimized due to the low concentration in the areas subjected to the higher rates of heat transfer.

As previously mentioned, perhaps the most important advantage of the dual circulation design for 100 per cent make-up is the appreciable reduction in the amount of silica in the steam leaving the boiler. The relation between the silica concentration in the boiler water and the concentration of silica in the steam has been shown by Prof. F. G. Straub.[2] Indications are that silica is vaporized in the steam drum of high pressure boilers and passes out with the steam as a vapor. Consequently, ordinary means for washing and drying steam to remove impurities do not affect the silica vapor and it passes into the turbine where it is deposited on the blades in the stages at which the temperature of the steam is approximately equivalent to the temperature at which the silica is vaporized. These deposits result in loss of turbine capacity and because of their nature are very difficult to remove. The quantity of silica vaporized in the boiler increases with the steam pressure and with the concentration of the silica in the boiler water from which the steam is released. On the other hand, the amount of silica vapor in the steam decreases with an increase in the pH of the boiler water. Assuming that the pH of the boiler water is maintained at a satisfactory level by the feedwater treatment the dual circulation principle results in a minimum production of silica vapor for two reasons. First, because the steam generated in the secondary section from highly concentrated boiler water is completely condensed in heating the incoming feedwater, hence contributes little, if any, silica to the steam leaving the boiler. Second, the steam leaving the boiler is produced in the primary section where the boiler water concentration is low.

[2] "Steam Turbine Blade Deposits," by F. G. Straub, Bulletin No. 364, Engineering Experiment Station, University of Illinois, 1946.



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The advantages of the dual circulation boiler over the conventional standard boiler are illustrated by the following example. The assumptions as to operating conditions stated below approximate those that will prevail in the Whiting installation.

(1) Drum operating pressure — approximately 1500 psi.

(2) Total soluble solids concentration in the feed water—150 ppm.

(3) Silica (SiO_2) in the feed water—1 ppm.

(4) Evaporation in the secondary section—33 per cent of the total output of the boiler.

(5) Moisture of steam leaving drier —0.1 per cent.

(6) pH of boiler water—not less than 10.0.

For various assumed per cents of blowdown the concentrations of solids and silica in the boiler and steam are shown in Table 1.

It should be noted that a blowdown of 18 per cent is necessary in the standard boiler to limit the boiler water concentration to the value of 1000 ppm. which is recommended by the ABMA for operating pressures from 1000 to 1500 psi. Under this condition it is assumed also that solids carryover with the steam will be 1 ppm with the standard boiler. It has been observed that when the total silica concentration in the boiler water is kept below 5 ppm and the pH of the boiler water in the vicinity of 11 there is comparative freedom from turbine deposits, and that deposits will not form if the silica content of the steam is kept below 0.1 ppm. The ease with which the dual circulation unit satisfies these limitations is readily apparent from Table 1.

The noteworthy features of the steam generating unit, which were dictated by the high make-up, apart from the dual circulation principle, are the large furnace volume, the isolation of certain

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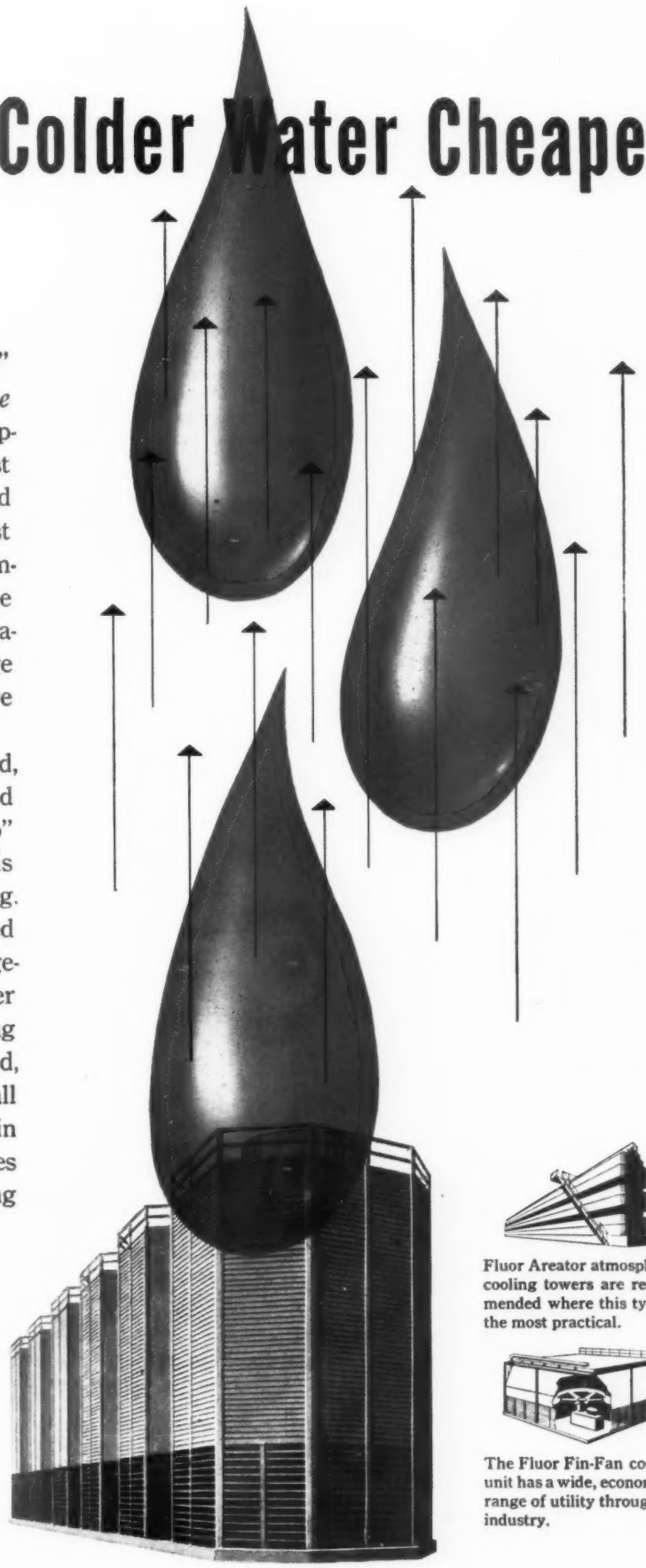

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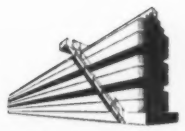

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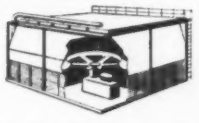

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tubes and groups of tubes to insure positive circulation, the absence of an economizer, and the unusually large steam drum to accommodate the complicated internals for washing and separating. The drum internals have been the subject of extensive investigation by Foster Wheeler Corporation including tests on a full sized cross-sectional element of the drum. Particular attention has been paid to reducing to a minimum the entrainment of steam in the water entering the downcomer tubes of the primary section, and to minimize the swell of water in the drum, and thus obtain substantial agreement between the actual level in the drum and the level indicated by the gauge glass. In line with the increase in furnace volume the six burners have been arranged in two vertical rows of three burners each. This has the effect of spreading the region of maximum heat input over a larger section of the furnace. Special care has also been taken to obtain as great a slope as possible to all tubes exposed to radiant heat. The walls forming the sides of the furnace hopper are inclined at 55 deg to the horizontal.

Steam temperature control is by means of dampers placed in the gas pass between the second section of the superheater and the convection section of the boiler. With the type of feed water available the heat exchanger type of superheat control is not feasible because of the danger from deposits. Continuous blowdown is from the upper drum of the convection section with intermittent blowoff from the lower drum and from the lower ends of the primary section downcomers.

TABLE 1.

Blowdown, per cent	Boiler water concentration, ppm.			Silica (SiO_2) in boiler water, ppm.			Total solids carryover in steam, ppm.		Silica (SiO_2) in steam, ppm.	
	Standard boiler	Dual circulation boiler		Standard boiler	Dual circulation boiler		Standard boiler	Dual circulation boiler	Standard boiler	Dual circulation boiler
	All tubes	Secondary section	Primary section	All tubes	Secondary section	Primary section				
1	15,150	15,150	445	101	101	2.97	15.1	0.45	1.01	0.030
5	3,150	3,150	415	21	21	2.76	3.2	0.42	0.21	0.028
10	1,650	1,650	384	11	11	2.56	1.7	0.38	0.11	0.026
18	1,000	1,000	352	6.7	6.7	2.36	1.0	0.35	0.07	0.024
20	900	900	340	6	6	2.36	0.9	0.34	0.06	0.023
30	650	650	310	4.3	4.3	2.06	0.7	0.31	0.04	0.021

● **Description of station.** The ultimate expansion of the station provides for six steam generating units, each having a capacity of 300,000 lb of steam per hr, and five 10,000-kw topping turbo-generators. Space is available for expansion of the water treating facilities to an ultimate capacity of 400,000 gal per hr, a total of five two-stage hot process softener units, including filters and auxiliary equipment. The initial installation consists of three steam generating units, two[3] 10,000-kw turbo-generators, and two hot process softener units.

The topping turbines are designed for throttle steam conditions of 1250 psi 900 F total temperature, and a back pressure of 400 psi. Under full load conditions the exhaust steam temperature will be approximately 650 F. In the initial installation one unit is of the reaction type beyond the first impulse stage, and one unit is of the straight impulse type. The generators are of the standard air-cooled type with air coolers mounted in the foundation below the generator. Each generator is equipped with a direct connected exciter and pilot exciter.

The topping turbines will exhaust into the refinery 400-psi steam distribution system, which is also supplied by the existing 400-psi boilers in stations No. 1 and 2. Steam is supplied at this pressure to process units in the refinery and to the existing non-condensing turbo-generators, which reduce the pressure further to approximately 100 psi. The 100-psi steam is also distributed to the refinery for power, process, and heating. Both 400-psi and 100-psi steam are transported through a network of distribution mains to distances of more than 4000 ft from the power station. To guard against accidental overloading of the generators, which might be caused by the rupture of a steam distribution main, or the sudden loss of one or more of the 400-psi boilers, resulting in a rapid drop in the exhaust pressure on the topping turbines, each high pressure turbo-generator is equipped with a load limiting device actuated by hydraulic pressure. This device will control the steam inlet valves, permitting the turbine to supply a limited electrical load and part of the steam requirements during the trouble period. It will also permit a rapid return to normal operation when the trouble has been isolated.

The load limiting device will respond to a back pressure approximately 25 psi below the normal range to close the turbine inlet valves until the back pressure is stabilized by the other sources of steam supply such as the pressure reducing stations or the 400-psi boilers. The pressure scale of the limit regulator will be such that for any back pressure established it will permit sufficient steam to pass to develop 125 per cent load or less. The regulator is designed to operate the inlet valves through full stroke in approximately one second, which is much faster than any drop in pressure that might occur in the system.

Under normal conditions the present 400-psi turbines and the new topping turbines will be operated by means of manual governor control to distribute load between the turbines and maintain the speed of the system. For this reason a back pressure regulating device will not be used to control the steam flow to the turbines but the balance between the electrical load and the steam demand will be maintained by means of automatic pressure reducing and desuperheating stations.

The principal features of the steam generating units have been described, particularly with respect to the novel character of the circulation system. The steam drum of the primary section has an inside diameter of 72 in. and a plate thickness of 4⅞ in. The upper drum of the secondary (convection) section is 48 in. ID and the lower or mud drum is 42 in. ID. The tubes in the convection section are 2½ in. OD and the tubes in the furnace walls are 3 in. OD. The downcomers for the primary and secondary circuits are 16 in. OD and the circulating tubes between the two circuits are 6 in. OD. The separation and drying in the steam drum are effected by centrifugal separators and chevron type dryers. The superheater is of the pendant type and is in two sections.

Each boiler is fired by six burners of the intervane type arranged for firing with fuel oil and refinery gas. Provision has been made to permit installation of internal elements for pulverized coal firing in the future. Accessibility to the burners is provided by means of a permanent platform at each pair of burners. An independent duct for the air supply is provided for each vertical row of three burners with damper control for each burner.

Heat recovery equipment consists of a regenerative type air preheater for each boiler. The total height of the elements is 60 in., with 12 in. at the cold

[3] A third 10,000-kw turbo-generator has recently been ordered.

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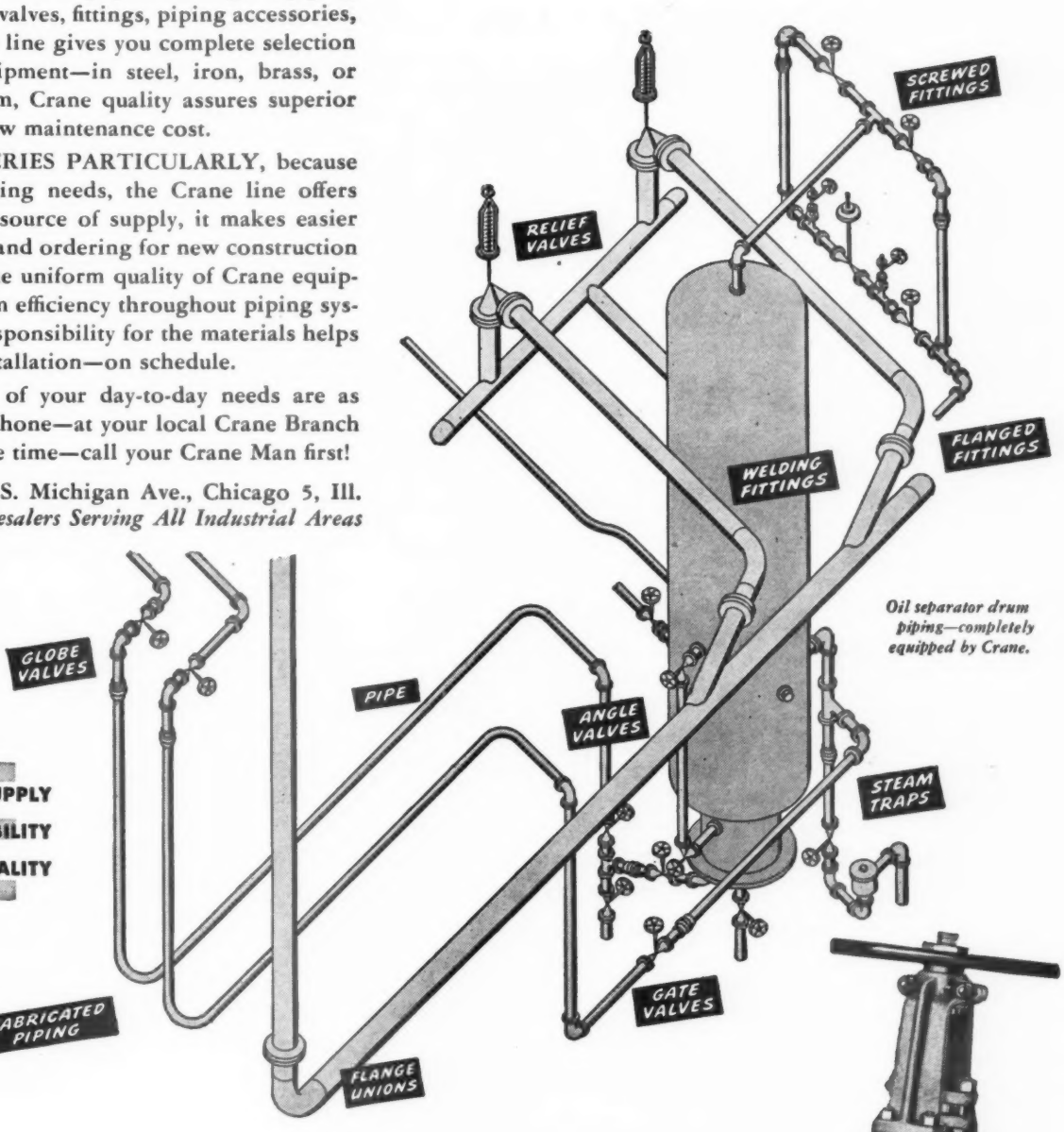

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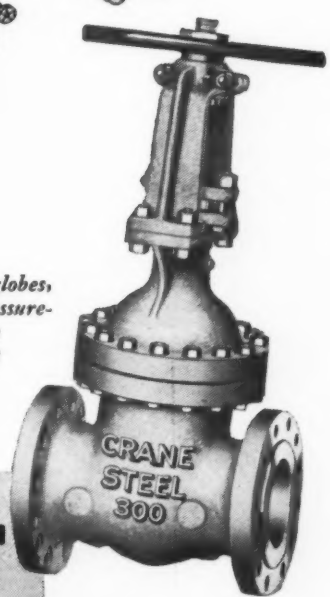

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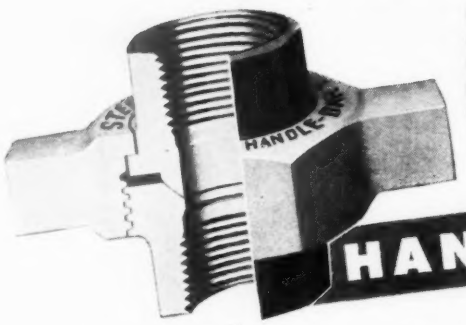

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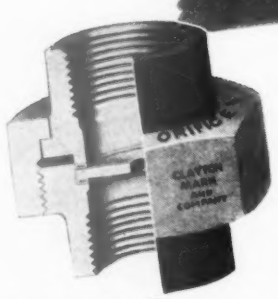

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Air for combustion is supplied by a forced draft fan driven by two constant speed motors. Control of the air supply is by means of inlet vanes and by shifting from one motor to the other through the combustion control. Air can be drawn through the intake ducts either from the upper part of the boiler room, or from outside the building, or can be proportioned by dampers as desired. Air intake louvers are provided in the walls of the boiler room near the main operating level.

Flue gases are removed by an induced draft fan, which is also driven by two constant speed motors. Control is similar to that provided for the forced draft fan. Both fans can also be controlled manually from the boiler gauge board. A separate stack supported from the roof framing is provided for each steam generating unit. Fans and air preheaters are housed in a separate room above the main boiler room. Space has been allowed in the layout for future installation of a mechanical type dust collector between the air preheater and the induced draft fan, and the fan has been designed to handle the increased draft loss involved.

With the exception of a retractable unit on each side of the furnace for cleaning the slag screen at the entrance to the convection bank, which will operate on 400-psi steam, all boiler soot blowers are designed for operation on the air puff system using compressed air at 300-psi pressure. All soot blowing units are under automatic control with indicators and controls mounted on the boiler gauge board. Air for soot blowing will be supplied by two horizontal tandem motor-driven compressors.

The design of the station has taken into account the possibility of future installation of pulverized coal burning equipment and provisions have been made in the layout for coal handling, storage, and preparation facilities, and for the removal and handling of ashes. For unloading, sizing and transportation of coal the existing facilities at Station No. 1 will be used. Coal will be carried to Station No. 3 by an extension of the present belt conveyors and will be discharged into storage bunkers to be situated above the central firing aisle. Space has been allowed for coal feeders, pulverizers, exhausters, and coal feed pipes to the burners, and the sub-base for pulverizers has been constructed below the boiler room floor. For the present the bottom of the furnace hopper is closed off by solid refractory but the design made provision for future ash storage hoppers and ash removal system.

In an industrial plant requiring both power and process steam the demands for these rarely parallel each other for any appreciable period. To a certain ex-

tent this condition can be satisfied by the selection of the steam pressures. The initial pressure must be high enough to permit generation of the maximum requirement for electrical power from the minimum demand for steam. Unless it is known positively that there will be no increase in the plant demands, future expansion must also be provided for by a sufficient surplus of generating capacity available from the topping cycle. The inequalities in the demands for steam and power are taken care of in the new station by steam conditioning equipment for reducing the initial pressure and temperature of the steam from the boilers to that of the exhaust from the topping turbines. For normal operation this function is supplied by two pressure reducing and desuperheating stations, one having a capacity up to 75,000 lb per hr, and a second with a capacity of 300,000 lb per hr. The larger unit is designed to cut in automatically when the smaller reaches the limit of its capacity. Two additional stations with a capacity of 300,000 lb per hr have been provided, of which one is a standby and one is provided to safeguard the steam supply to the refinery in the event that one of the topping units should trip out. It is expected that this installation of steam conditioning equipment will be sufficient to serve the ultimate plant. Each pressure reducing and desuperheating station consists of a diaphragm operated pressure reducing valve of the pilot type and a steam jet water spray nozzle type desuperheater. Condensate for the spray water is obtained by condensing the vapor from the deaerating heaters in oversize vent condensers with relatively cold raw water on its way to the feedwater treating plant. The condensate is deaerated in a separate section of the deareator and collected in a compartment of the deaerator storage tank. When the supply of condensate is greater than the demand it overflows into the adjacent compartments of the storage tank containing deaerated boiler feed water. For emergencies a supply of condensate is stored in a 30,000-gal tank situated at the level of the daerator storage tanks. The pumps for handling desuperheater spray water are on the main operating floor adjacent to the boiler feed pumps. All controls for the steam conditioning equipment are on a panelboard at the main operating level. The noise associated with the reduction in pressure in valves of the type usually employed for this service is quite objectionable to the operators especially when this equipment is in the vicinity of operating stations. Considerable improvement has been effected by changes in the design of valves and piping in recent installations and the noise level has been appreciably lowered. In this installation, because of the large number of units involved, it was considered desirable to isolate this equipment as much as possible, therefore all pressure reducing valves and desuperheaters for the 1250-psi to 400-psi service, as well as additional units for 400 psi to 100 psi and 100 psi to 10 psi, have been placed in a separate room above the roof of the

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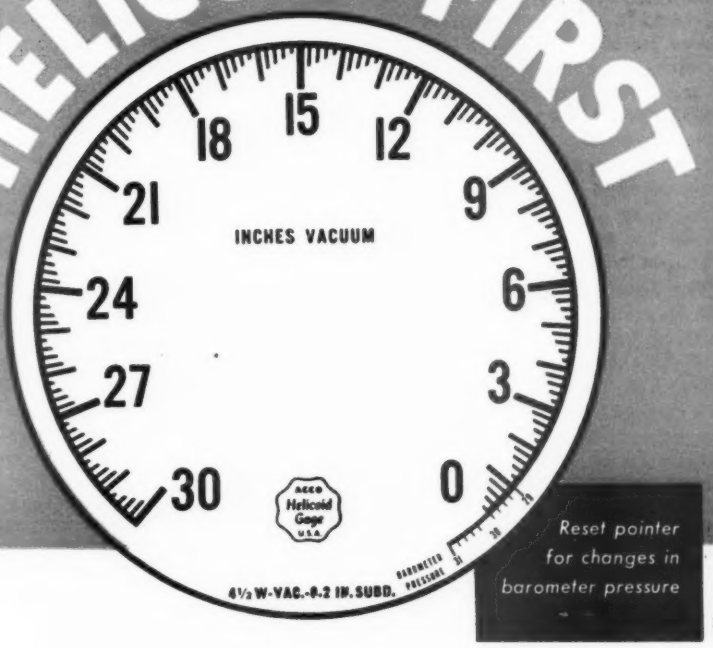

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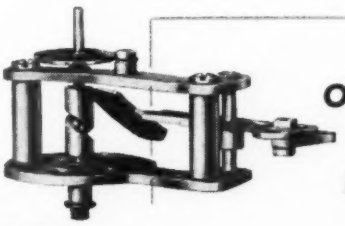

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turbine room and isolated from the boiler room by a solid brick wall. The walls of this room will be lined with acoustic material to further deaden the sound and contribute to the comfort of those required to work in this space.

Due to the nature of the plant the feed-water treating system is of special interest. It is situated adjacent to the power station and is laid out to permit an ultimate expansion equivalent to that of the steam generating capacity. The initial installation consists of three lime-soda sedimentation tanks, one of which will serve as a spare, and two phosphate sedimentation tanks. Each pair of tanks comprising a unit has a net capacity of 80,000 gal per hr and each tank has a retention time of 1½ hr.

The chemicals for water treatment will be stored in bags and barrels in a building having a storage area of 4700 sq ft. The storage room is adjacent to a railroad siding with its floor at the level of a railroad car. The chemical mixing and proportioning room is next to the storage room. The mixing tanks are slightly above grade elevation and arranged to permit dumping of the chemical charges from a platform connecting with and at the same level as the storage room floor. Separate tanks are provided for mixing lime and soda, phosphate, and retardant solutions and each tank is equipped with its own agitator, proportioning mechanism, pump suction tank, and chemical pump. The controls for all chemical proportioning and feeding mechanisms and pumps are mounted on a central control board on which are also mounted all flow and level recorders, pressure gages and other instruments required for control of the entire feed water treating system.

Each sedimentation tank is equipped with means for recirculating sludge from the sludge cone to the top of the tank for the purpose of accelerating the precipitation. This consists of an ejector, a flow meter, and a clear water pump. The ejector and flow meter are placed adjacent to the tank to reduce the length of the sludge pipes. The clear water pumps for all tanks are in mixing room.

The source of the raw water supplied to the power station for boiler feed purposes has been described. All raw water is discharged for presettling and storage into two 50-ft by 50-ft tanks adjacent to the water treating plant at Station No. 1. The temperature of the incoming raw water varies with the season of the year and with changes in process operations over a normal range of 120 F to 180 F. Water to Station No. 3 will flow through two 18-in. lines to the raw water pumps situated in the pump bay of the boiler room, thence through the vent condensers on the deaerating heaters to the spray heaters of the sedimentation tanks. In an emergency the raw water pumps can take suction from the cooling water supply system of the refinery, which may have a temperature of 40 F or less in winter. Under emergency conditions, with a water temperature entering the deaerator vent condensers of 40 F, the outlet temperature will be 162 F. At maximum capacity, with a temperature of 180 F entering the vent condensers, the outlet temperature will be 238 F. In the sedimentation tanks the temperature will be raised to 240 F corresponding to an exhaust steam pressure of 10 psi. Full capacity of the treating tanks can be maintained with a raw water inlet temperature as low as 90 F. Steam for heating in the treating tanks is supplied from the refinery exhaust steam mains and from the continuous blowdown flash drums. Because of the danger of contamination with oil from reciprocating steam drives refinery exhaust steam is not permitted to enter the deaerators. The steam for deaeration comes from turbine drives within the station or from the low pressure turbo-generator units in Station No. 1.

The effluent from the phosphate sedimentation tanks flows through conventional type pressure filters using anthracite coal as the filtering medium. Backwash pumps are situated in the chemical building mixing room and are two in number with motor drives. All sedimentation tanks and filters are out-of-doors with stairs and platforms for access to all valves and other equipment requiring servicing. The structure supporting the pipes leading to and from the boiler room has been made to serve also as a bridge to the platforms at the top of the sedimentation tanks thus permitting the operators to use the elevator in the boiler room for access to the upper levels.

The sedimentation tanks are equipped with automatic sludge blow-down valves for continuous withdrawal of sludge precipitated in the bottom cone. To facilitate sludge removal the bottom cone of the tanks is constructed with an included angle of 70 deg instead of the usual 90 deg. Quick opening valves for intermittent de-sludging are also provided. Sludge is withdrawn through pipes leading to an underground tank in which the vapor is released before being discharged to the refinery sewer system. A similar arrangement at Stanolind Station No. 2 has given trouble due to the carryover of precipitates with the vapor from the sludge tank. The vapor from the sludge flask tank at Station No. 3 is condensed in a jet condenser installed in the vent pipe. The condensing medium is the cooling water discharged from the generator air and oil coolers but water from the refinery cooling water system can also be used. The design of the condenser is similar to that of an ordinary barometric condenser.

Power is generated at 13,800 volts, 3 phase, 60 cycles. The 13,800-volt switchgear is installed in an electrical bay adjoining the turbine room at the main operating level with reactors situated on a mezzanine floor at grade 24. A room for the control storage battery is also on this floor. Power is distributed to the refinery at 13,800 volts through underground ducts by way of a series of cable vaults situated just outside of the electrical bay. The motors driving fans and boiler feed pumps are supplied at 2300 volts from switchgear that is above the pump bay at the fan floor level.

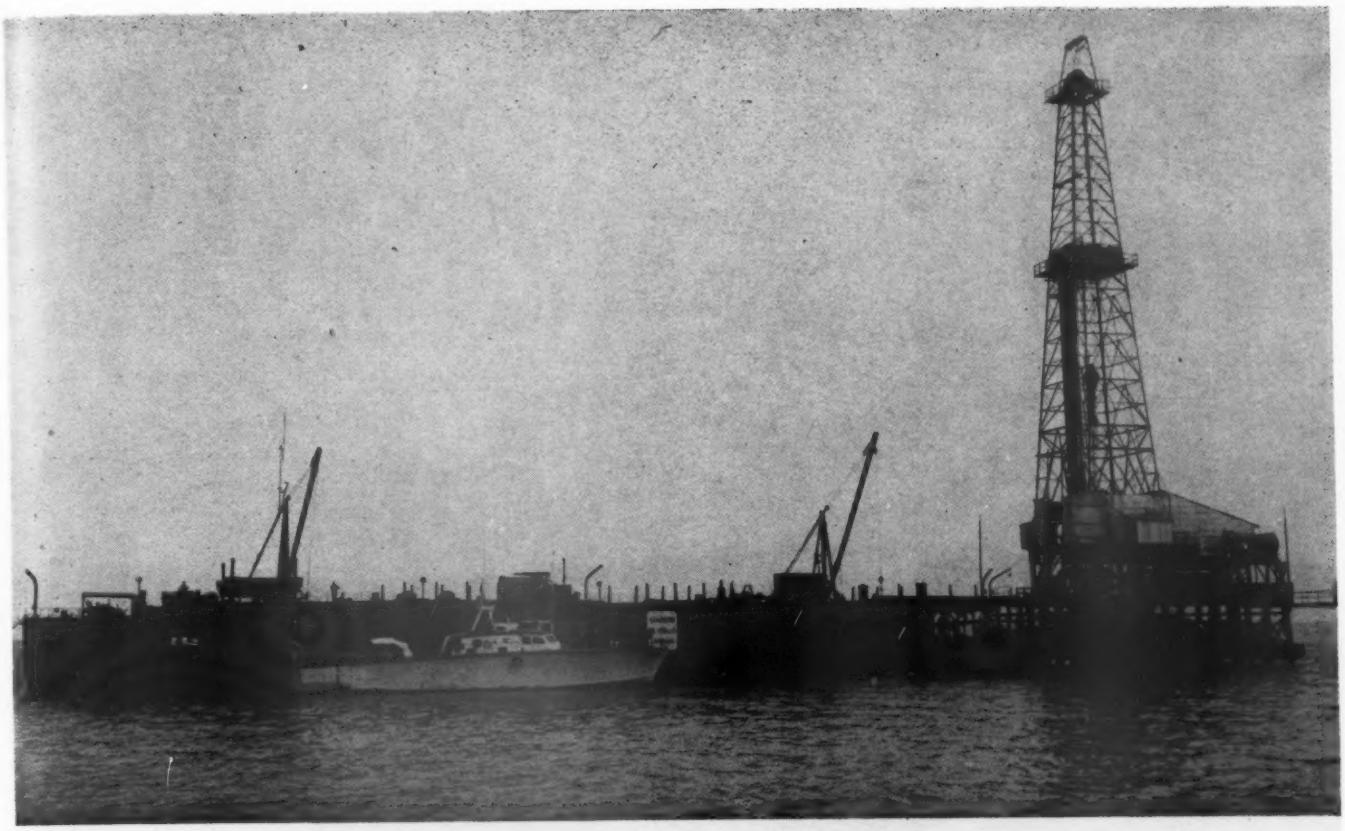
The ultimate development of the main electrical system will consist of five 13,800-volt unit busses, each unit bus being tied through a circuit breaker and reactor to the synchronizing bus. To each unit bus will be connected a 12,500-kva generator and four 6500-kva refinery feeder circuits. The refinery feeder circuits will supply a number of 2500-kva, 13,800/4160-volt double ended unit substations on a spot network system, insuring a high degree of reliability in electrical distribution to refinery loads.

The ultimate development calls for three 2300-volt station auxiliary busses, each bus supplying the auxiliaries for two boilers. Each 2300-volt station auxiliary bus will be fed normally from a 13,800-volt unit bus through a 6250-kva transformer with automatic throw-over to a 2300-volt emergency bus supplied from Stanolind Station No. 1. The 440-volt station auxiliary busses will be three in number, normally supplied from their respective 2300-volt station auxiliary busses through 500-kva transformers with automatic throw-over to a 440-volt emergency bus supplied from Stanolind Station No. 1. The electrically driven station auxiliaries are thus insured of a reliable supply of power, reasonably free from interruption.

The station lighting is supplied from a 150-kva transformer connected to one of the 2300-volt station auxiliary busses. A number of emergency lights are placed throughout the station and are automatically energized from the 125-volt control storage battery in event of failure of the normal lighting.

The principal controls for the station are on the main operating level. Instruments for controlling boiler operation are mounted on panel boards in the firing aisle in front of each unit. Because of the variable nature of the fuels and the likelihood that two or more fuels will be burned simultaneously, control of combustion conditions will be aided by an oxygen recorder rather than the usual CO_2 recorder. A further aid in maintaining proper combustion will be a smoke indicator and recorder. Both the smoke recorder and the oxygen recorder will be mounted on the boiler gauge boards. The bi-color water level gauges will be visible form a station adjacent to the gauge boards and a water level recorder will be provided. A recorder is also being installed to keep a continuous record of the conductivity of the steam leaving each unit. Automatic soot blower controls for steam and air puff units are on boiler gauge boards.

Steam flow meters, master controls, and all controls for the pressure reducing and desuperheating stations, and various pressure and temperature indicators and recorders are mounted on two panel boards installed back to back to form an enclosed space and are placed at the end of the firing aisle in the pump bay adjacent to the turbine room. A separate panel board is provided for each turbo-generator unit situated conveniently to the unit. Other panel boards are provided for control of boiler blowdown, fuel oil and water pumps, etc. For improved visibility, all panel boards will be painted pearl gray. ★★★



LCT (the Dean Terrill) and air-sea rescue ship (the T. M. Kerr) are tied up to the leeward side of the YF. drilling barge (the Frank Phillips) at Block 28 drilling well. The barge is tied to three 19-pile timber dolphins adajcent to heavy steel pipe drilling platform. It can be pulled away from platform in case of a storm.

Operating problems in the Gulf tidelands

By K. MARSHALL FAGIN, *Field Editor*

EXCLUSIVE

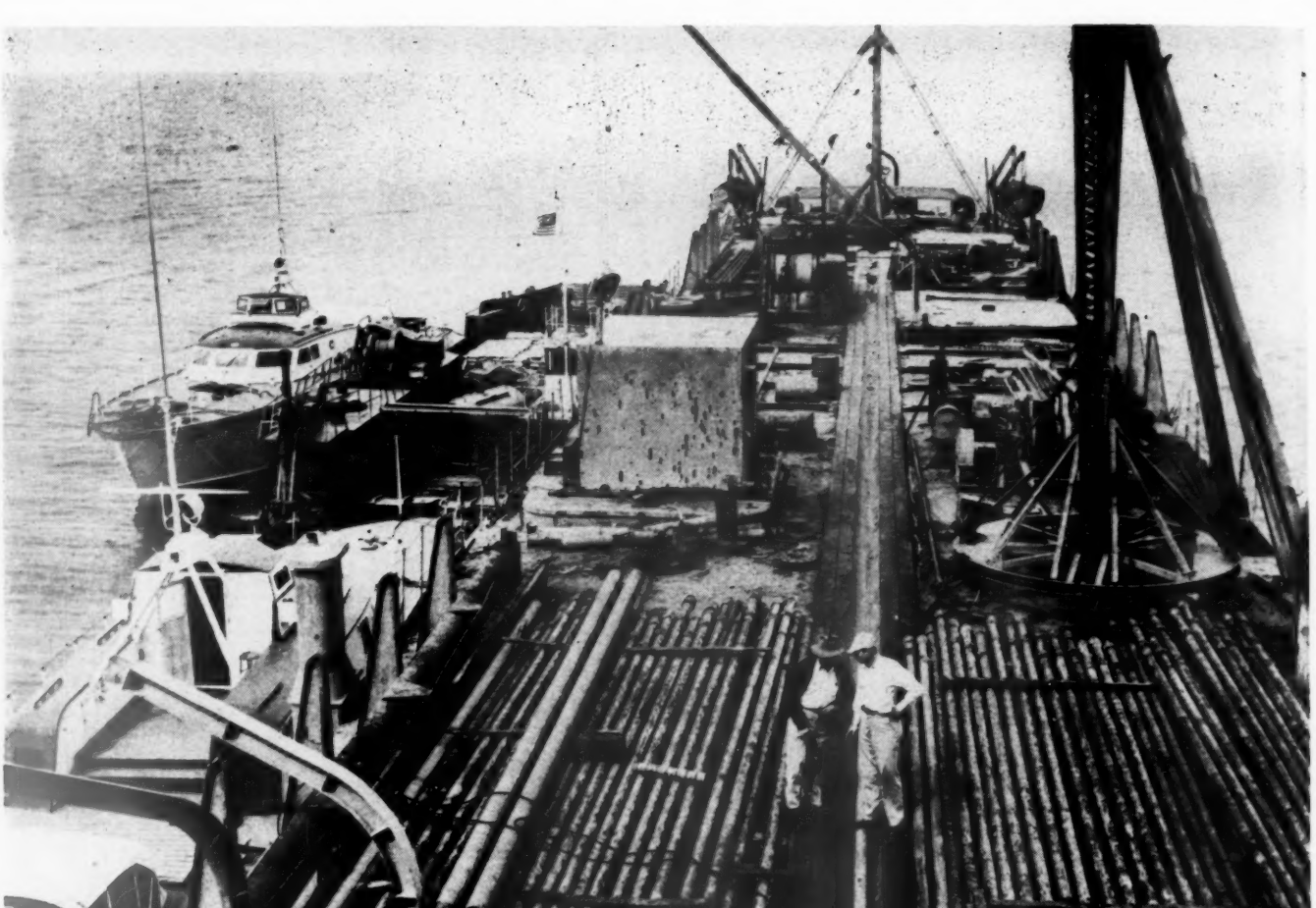
As our ship, the Robert S. Kerr, circled helplessly around for more than an hour in an early morning fog that covered Atchafalaya Bay, we realized the truth of a statement made by our host, Dean A. McGee, executive vice president of Kerr-McGee Oil Industries, Inc., that "the weather is the biggest problem that faces the operators of offshore drilling and producing wells." The fog that morning delayed the delivery of a special wellhead flange that had been flown to the shore base at Berwick, Louisiana, so that drilling could be resumed on the company's deep test at the Block 28 well, which is about 50 miles from the shore base and 25 miles southeast of Eugene Lighthouse. Delays like this might be very serious as well as expensive, especially when one thinks of the emergencies that might arise and realizes that it costs about $3000 per day to operate an offshore drilling rig.

The pilot might have kept the boat on the regular course across the bay with his compass, but it had not been calibrated since a new steel pilots' house was completed a day or two before. Even so, the channel across the bay is narrow and the shallow water on the mud-filled bottom is hazardous for boats with as much as a 4-ft draft. When the fog lifted we sighted a marker buoy and proceeded to Eugene Island. The weather was clear and fine from there to the Block 28 well, where we had lunch and observed the equipment employed in drilling this deep offshore wildcat. On the return trip that evening, we visited Kerr-McGee's Block 32 shallow oil well, the first well they drilled, and the first oil well discovered offshore since the Superior Oil Company discovered the Creole field, about 1 mile off the shore of Cameron Parish, in March, 1928.* Several offshore wells were drilled in the meantime† and others are now drilling or being rigged up in the urgent search for new petroleum reserves.

● **Offshore structures.** More than 50 salt domes or potential oil-producing structures have been found in the 27-marine-mile strip of submerged land adjoining the State of Louisiana, and geologists estimate that this 5,000,000-acre area might produce more than 10,000,000,000 bbl of crude oil. About 2,000,000

*See "Gulf Leasing Foreshadows Much Drilling" in *The Petroleum Engineer*, May, 1947, pages 49 to 52, inclusive.

†See "Magnolia Drills for Oil in Gulf of Mexico" in *The Petroleum Engineer*, November, 1946, pages 82 to 94, inclusive.



Top of drilling barge seen from V-side of derrick floor shows drill pipe racks, derrick cranes, electric logging unit, electric cable drawworks, etc. Supplies are being unloaded from LCT. Two 85-ft air-sea rescue ships are tied up on leeward side. Steel pipe gutter in center of central catwalk guides joints as they are pulled up ramp and into derrick.

acres have been leased by the State of Louisiana for an initial bonus of $15,000,000, and the annual rental (in lieu of drilling) amounts to one-half that amount. It is obvious that the sooner the companies begin to drill, the more they will save in rental payments, and the sooner they will discover producing fields and begin to recover their capital and hope to share in the profits.

With the tremendous investment required for special over-water drilling equipment, shore bases, and boats, however, the economics of drilling and producing offshore leases looms as the second biggest problem facing offshore operators. Kerr-McGee solved this problem by taking in Stanolind Oil and Gas Company and the Phillips Petroleum Company as partners in their two 20,000-acre lease blocks. Phillips acquired one-half interest and Stanolind acquired three-eighths interest, but Kerr-McGee retained operating rights on these leases for which they had paid the state a bonus of $317,500 in 1946.

The salt dome type structures under these leases had been indicated by extensive and expensive seismograph surveys of the area. The risks involved in drilling and development of these struc-

TABLE 1. Production record, November 15-18, 1947, Block 32 well.

Date test	Hour ending	Well status	Bbl produced	Choke size	Tubing pressure	Casing pressure	BSW, per cent	Gravity, API
15	5:50 p.m.	Fl	43	11/64-in.	47 lb		5.0	25°
	6:50		39				4.0	
	7:50		39				4.0	
	8:50		35				3.0	
	9:50		39		44		3.0	
	10:50		37		47		2.4	
	11:50		37		45		3.0	
16	12:50		36		42		4.0	
	1:50		40				4.0	
	2:50		44				3.0	
	3:50		42				4.0	
	4:50		36				3.0	
	5:50		31				4.0	
	6:50		32				3.0	
	7:50		33				2.0	
	(Well off test)							
16	11:50 p.m.	Fl	32	1/4-in.	70	200	0.2	25°
17	12:50 a.m.		36		68		0.2	
	1:50		38		70		0.3	
	2:50		38				0.3	
	3:50		38				0.2	
	4:50		40				0.2	
	5:50		39				0.2	
	6:50		40				0.1	
	(Strong east wind, sea rough, expecting to cut loose)							
	(Well off test)							
17	(Well shut in at 8:45 a.m. Shut in pressure 200 psi tubing pressure, 300 psi casing pressure)							
18	(Well opened at 12:00 noon on 1/2-in. choke)							
	1:00 p.m.	Fl	66	1/2-in.	100	225	0.8	25°
	2:00		48		90	225	0.4	
	3:00		44		90	225	0.4	
	4:00		37		80	200	0.4	
	5:00		37		82		0.4	
	6:00		11	1/4-in.	100		0.2	
	7:00		11		120		0.6	
	8:00		20		130		0.6	
	9:00		18		140		0.4	
	10:00		16		140		0.4	

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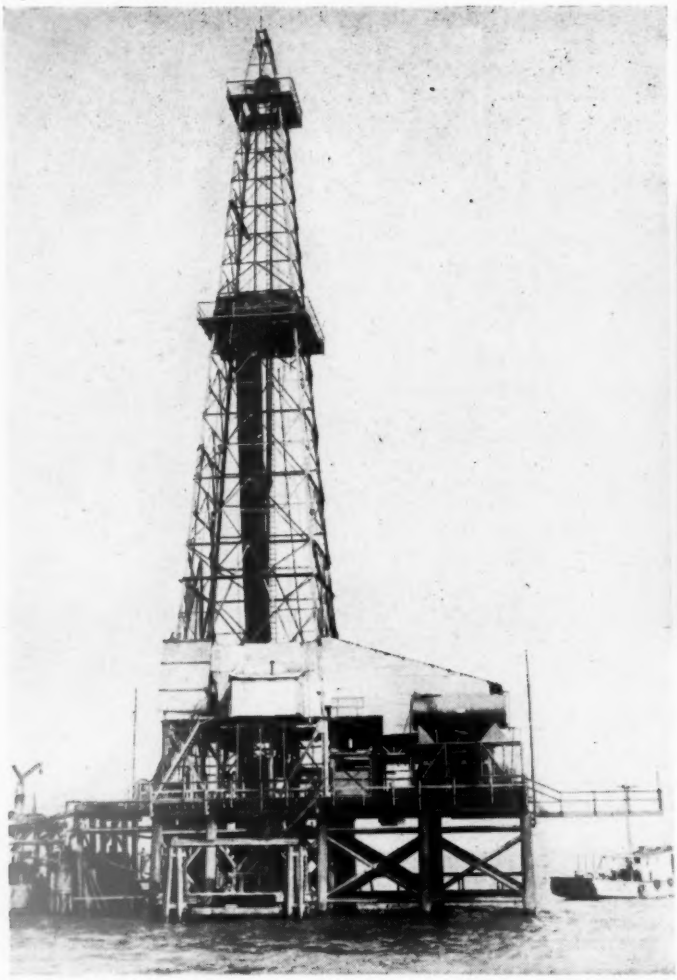


Dean A. McGee, executive vice president of Kerr-McGee, uses two-way FM radio set on drilling barge to check weather at Berwick, Louisiana, shore base.

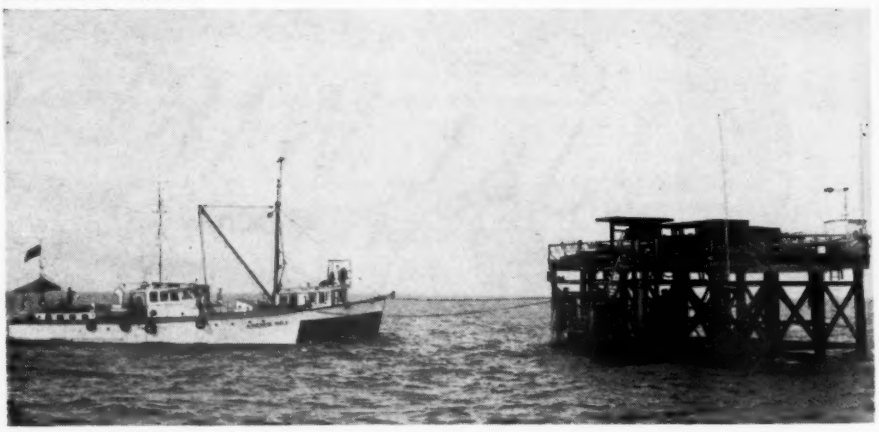
Drilling platform is supported by steel pipe piles. Derrick is designed to withstand hurricane winds up to 125 mph without guy wires. Safety catwalk extending from right of platform provides a way for crew to escape to boat during storms.

Seismograph crew boats are tied up to Block 32 well platform. Wellhead connections are under platform. Equipment on platform is to be used in drilling directional wells.

tures appeared so enormous that Kerr-McGee decided that a one-eighth interest and operating rights would be enough to keep.

● **A drilling fleet is expensive.** The operators set to work on their drilling plans early in 1947. A fleet of ships was purchased and outfitted for the marine drilling work. Three 85-ft air-sea rescue ships were purchased from the U. S. Navy surplus pool. These cost Kerr-McGee $20,000 each, although the Navy had paid more than $80,000 for them. A 63-ft air-sea rescue ship; 2 LCT's (landing craft for tanks), and a huge YF barge were also purchased from surplus for the initial fleet.

The 260-ft by 48-ft YF barge cost Kerr-McGee about $230,000, including $75,000 for the initial purchase and $155,000 for converting it into a drilling barge. Unlike the usual drilling barges, the YF is not submerged to the sea floor at the well location, and it does not carry the drilling rig, drawworks, and engines. Instead, it is tied securely to three 19-timber pile dolphins on one side of a 44 by 78-ft steel pipe drilling platform, and anchored to the bottom by five heavy wire ropes. Four of the anchor ropes extend out to the side from the fore and aft ends of the barge, and the fifth anchor rope extends out to the rear. In case of stormy weather, the YF drilling barge can be disconnected from the dolphins and pulled away from platform toward the stern anchor by special winches.



● **Small drilling platforms are used.** Heavy 24-in. pipe pilings were welded into 140-ft lengths and hauled in the LCT's from the shore base at Berwick to the Block 32 well location, the site of the first Kerr-McGee drilling platform. This platform was a little smaller than the one at Block 28. The water was 18 ft deep instead of 12 ft deep, however, so the cost was about the same, or $260,000. Part of this platform might be salvaged if a well was completed as a dry hole. The 24-in. pipe pilings could be cut off 8 to 12 ft beneath the ocean floor. Then the platform could be raised and towed on submerged barges to a new location. One the other hand, the platform could be reinforced to stand for many years by driving heavy steel H-beams inside the 24-in. pipe and filling the pipe with cement. Then, when the salt water finally corroded the steel pipe, the cement would protect the H-beam that would support the platform.

The platforms built by Kerr-McGee are about 20 ft above mean low tide, and the rig floor is on a 13-ft substructure that is erected on the platform. This is shown in the accompanying photographs. The platforms are large enough so that as many as 16 wells might be drilled directionally from it. The 24-in. pipe pilings are braced with 9⅝-in. steel pipes welded between them.

A 136-ft steel drilling derrick with a 30 by 30-ft base is used on the 13-ft substructure to handle the drill pipe and casing for 10,000 to 12,000-ft wells. The derrick is designed to withstand hurricane winds of as much as 125 miles per

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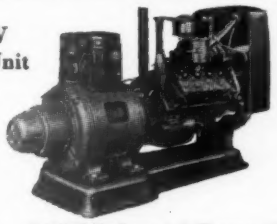

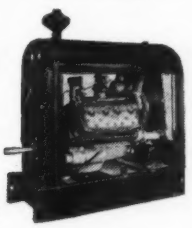

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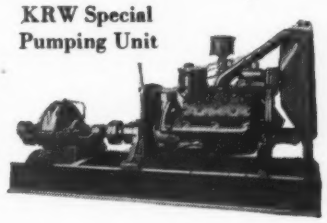

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hour without the use of guy wires. The platform supports the weight of the substructure, derrick, rotary table, drill pipe, drawworks, drilling engines, small fuel oil tanks, a water tank, and a small reserve mud tank and mud pump for emergency use, when the drilling barge is disconnected from the platform.

● **Huge barge equipped for offshore drilling service.** The 260 by 48-ft YF drilling barge contains all the other drilling equipment needed for the marine operation. Reserve and operating mud pits are in the lower or hull section of the steel barge. A 3500-bbl compartment for drilling water, a 20,000-gal compartment for fuel oil storage, a 20,000-gal compartment for drinking water, a diesel-electric generating plant, and auxiliary engines are also on the lower deck.

The galley, electric refrigerators, sleeping quarters for 30 men, radio communications room, dry storage for about 12 boxcar loads of mud materials and cement, two diesel-driven drilling mud pumps, a machine shop, and a skid-mounted well cementing unit are the principal items on the second or middle deck. The middle and lower decks are ventilated by a 50,000 cu-ft-per-min exhaust fan situated on the top deck.

The top deck of the barge is equipped with pipe and casing racks, a derrick crane at each end for loading and unloading purposes, an electric logging unit, a sidewall coring unit, life boats, life preservers, and floodlights.

TABLE 2. Summary of bottom-hole pressure tests on Kerr-McGee Oil Industries et al. No. 1 State.

Run No. 1—Static bottom-hole pressure:	
Date	12/4/47
Stabilization period	120 hr
Tubing pressure	115 psig
Fluid level	Not definite
Depth of survey	1700 ft
Depth to datum (midpoint of perforations)	1725 ft
Pressure at survey depth	770 psi
Correction to datum (25×0.380)	10 psi
Pressure at datum	780 psi
Fluid gradient	0.380 lb/ft
Run No. 2—Flowing bottom-hole pressure:	
Date	12/4/47
Choke	¼"x6" positive
Duration of test	5 hr
Tubing pressure	136 psig
Static bottom-hole pressure	780 psi
Flowing bottom-hole pressure (at 1700 ft)	633 psi
Correction to datum (25×0.380)	9 psi
Flowing bottom-hole pressure (at datum)	642 psi
Fluid production during test period	101 bbl
Calculated fluid production per day	484.8 bbl
Pressure drawdown (780-642)	138 psi
Productivity index (484.8÷138)	3.513
Run No. 3—Flowing bottom-hole pressure:	
Date	12/5/47
Choke	½"x6" positive
Duration of test	7 hr
Tubing pressure	Fluctuated
Static bottom-hole pressure	780 psi
Flowing bottom-hole pressure (maximum)	584 psi
Flowing bottom-hole pressure (minimum)	446 psi
Fluid production during test period	190 bbl
Calculated fluid production per day	651.43 bb
Pressure drawdown (minimum)	196 psi
Pressure drawdown (maximum)	334 psi
Productivity Index (maximum)	3.323
Productivity Index (minimum)	1.950

Note: During the period of testing on a ½-in. choke the well produced by heads so that exact evaluation of the Productivity Index is not possible. Some figures between 3.323 and 1.950 is postulated.

● **FM radio telephones used.** The drilling barge and several of the boats used in the Kerr-McGee fleet are equipped with two-way FM radio sets for instant communication at any time between any of the sets on the network. The receivers are kept on at all times, so that when some one speaks into one of the transmitters, he is heard on all other receivers tuned into the network. This is especially valuable for reporting the drilling progress of the well, ordering special parts or materials that are needed, and for transmitting weather forecasts and data. Portable two-way sets are to be installed soon in one or two of the company's automobiles that are used in Berwick-Morgan City area.

About 27 men are employed on the barge when drilling is in progress. Two drilling crews of six men each work alternate 12-hr tours for 7-day periods. Then two other drilling crews work the next seven days, while the first two crews go ashore. Thus, two drilling crews are on the barge one week and two other crews are on it the following week.

Five of the men on the drilling crew work on the drilling platform, and the sixth supervises the mud pumps and other drilling equipment on the barge.

About 15 other men live on the barge, including four seamen, four cooks, two toolpushers, a geologist, a petroleum engineer, a drilling superintendent, and a cementing or electric logging crew. Kerr-McGee has not experienced much difficulty keeping employes satisfied with the drilling life on a barge. The cooks keep the galley open 24 hr per day and serve a variety of good foods and coffee at all hours. ★★★

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(1) Switchboard instruments

A new line of long-scale switchboard instruments employing bearings with spring-mounted jewels that work to protect the pivots even under conditions of abnormal shock or abuse has been announced by General Electric's meter and instrument divisions.

The new Type AB-15 (a-c) and DB-15 (d-c) instruments are designed for general switchboard use by electric utilities and large industries.

The new instruments have scales 7.1 in. long spanning 250 deg about the center. To facilitate correlation of the numerals with the proper scale divisions, numbered major divisions are accented. All legends, such as "a-c amperes" etc., are placed below the center of the scale and thus are never partially covered by the pointer. All scale numerals are horzontally placed to facilitate readings.

The new bearing construction permits hard use without harm to the pivots. If, due to shock, the pressure of the pivot on the jewel is appreciably higher than normal, the jewel merely recedes into the screw. Before the jewel hits bottom, the shoulder on the end of the shaft strikes the top of the jewel screw and takes the shock, thus protecting the jewel and pivot.

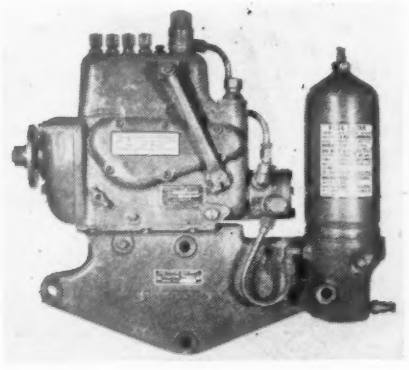
The instruments can be easily disassembled for inspection or repair. Moving elements can be withdrawn from the mechanism without disturbing the control springs or the jeweling. This means that the assemblies can be removed and replaced without noticeable change in the scale distribution, resulting in reduced maintenance costs and often eliminating the need for recalibration and repair.

The mounting dimensions and general case size has not been changed. Types AB-15 and DB-15 are mechanically interchangeable with older Types AB-13 and DB-13.

(2) Diesel fuel pump

The Industrial Power Division of International Harvester Company announces a field replacement package unit containing a new single-plunger International diesel fuel injection pump for replacing the older four-plunger pumps found on series "35" and series "40" diesel engines. New high pressure fuel lines and all necessary accessories are included. No modifications are required to install the new unit. Cost of the unit is less than the expense of a major overhaul on the old pump.

Features of the new single-plunger pump include faster governor action and more accurate fuel metering and injection. These features result in smoother engine operation and increased engine torque for maintaining constant rpm when operating under intermittent load conditions.



(3) Silent chain drives

Link-Belt Company announces that as a further step in the process of augmenting and constantly improving the Link-Belt line of power transmission, they have developed stock silent chain that will operate on sprockets cut to the new Industrial - Standard tooth form; and Link-Belt stock silent chain sprockets will fit the new Industrial-Standard silent chain.

This new Industrial-Standard stock-drive chain is now available in middle-guide type in two pitch sizes: ½-in. (SC-4) in widths of ¾ in., 1 in., 1½ in., 2 in., 2½ in., 3 in., and 3½ in. ¾ in. (SC-6) in widths of 2 in., 3 in., 4 in., and 5 in.

In a new 48-page Link-Belt Book No. 2125 covering Industrial-Standard silent chain drives, complete stock drives in sizes from ½ to 50 hp are tabulated in easy-to-use selection tables.

Aside from this ease of selection, and the interchangeability because of the new tooth form, the new book stresses:

Taper-lock bushings, tapered for easy assembly into taper-bored sprocket hub, tight fit on shaft, and easy removal. No reboring is necessary. Made of gray iron having a high steel content.

All-steel pinions with hardened teeth, and 1-⅛-in. long hub on one side. Carried in stock with finished bores for standard NEMA frame motor shaft diameters, complete with keyway and setscrew.

(4) Pipe wiper

United States Rubber Company is now producing a double-lip pipe wiper for use in wiping oil well drill pipe. The wiper is made of natural rubber in 14 and 17 in. sizes to fit any pipe. The hub of the wiper is designed to stretch over joints and fit neatly around the pipe. Mud is removed by a double wiping action when the drill pipe is pulled up out of the hole.

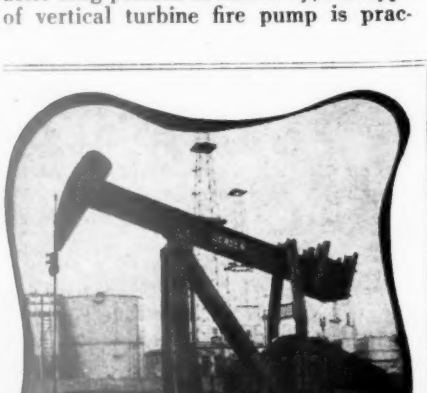
(5) Fire pump

Full approval by Underwriters' Laboratories, Inc., and Associated Factory Mutual Fire Insurance Companies has been granted to Peerless vertical turbine fire pumps, it has been announced by Peerless Pump Division of the Food Machinery Corporation.

The approval of the vertical turbine type fire pump aguments the extensive line of fully approved Peerless horizontal centrifugal fire pumps (formerly Dayton-Dowd).

Affording a reliable water supply for essential plant fire protection and especially designed for instant operation even after long periods of inactivity, this type of vertical turbine fire pump is practically impervious to deterioration, permits installation in minimum floor space, and allows an extremely simplified discharge piping layout, the manufacturer states. They are available in capacity ranges from 500 to 2000 gpm to operate against heads from 240 to 285 ft.

Peerless vertical turbine fire pumps are especially suited to pumping from wells, tanks, lakes, rivers, or sumps. Owners have a choice of not only oil or water lubrication but also a choice of drives, either electric or right-angle gear drive, or steam turbine drive, as the Underwriters' Laboratories has approved both methods of lubrication as well as all above mentioned types of drive.



JENSENS
Balance
Any Well

Crank and beam weights and adjustable stroke lengths enable a Jensen to be easily and accurately balanced to meet any well condition. Along with roller bearings and precision machined and shaved gears, the flow of power is smooth—steady. Fuel consumption is lower, upkeep and maintenance costs are reduced.

These savings in production costs can be yours by merely consulting your Jensen dealer or writing to us in Coffeyville. Do it today.

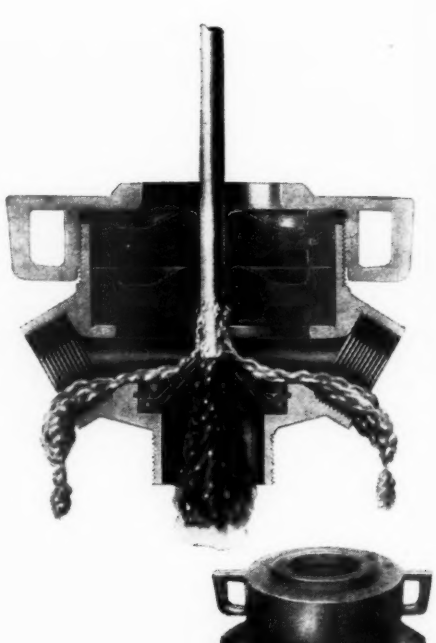
JENSEN
BROTHERS MFG. CO.
Coffeyville, Kansas, U. S. A.
Export Office: 50 CHURCH STREET
NEW YORK CITY

(6) Sucker rod wiper

A compact new Patterson-Ballagh sucker rod wiper, code: Subagent, strips oil and paraffin from all size rods, squares, and couplings. Improved design of the rubber wiping elements allows expansions from ½ in. to 2⅜ in., which is a great advantage in wiping combination strings. Rods may be pulled as fast as necessary with no oil flipping out on the crew.

A small conical rubber wiping element below two main wiping elements acts as a one way valve. It prevents paraffin that has been stripped from falling back into the hole. The main wiping elements will take enough pressure to allow crude oil to flow to tank if well makes a head.

The compact design of this wiper allows right height for wrenching. It is available with any standard connecting threads and with a spark-proof lid when requested. The main rubber wiping elements can be supplied with oversized wiping hole.

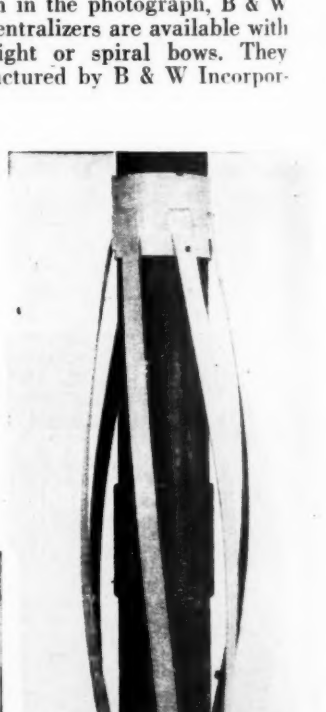


(7) Latch-on centralizers

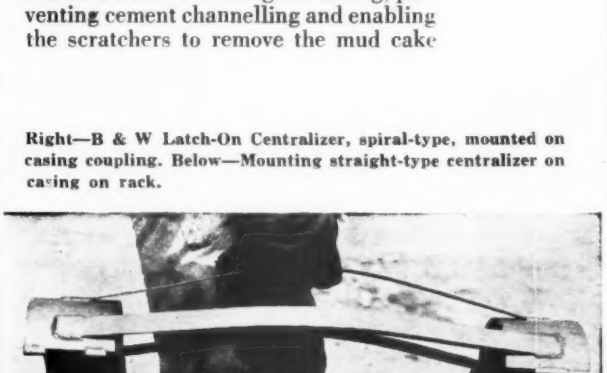
The new B & W Latch-on Centralizers are hinged for easy installation on the casing rack, or at the rotary table as casing is being run. They may be mounted at any position on the joint by latching them around a split collar welded to the casing or they may be latched around a casing coupling or external upset joint. They may be securely locked in position by driving the steel hinge pins in place, and the hinges and pins may also be tack-welded.

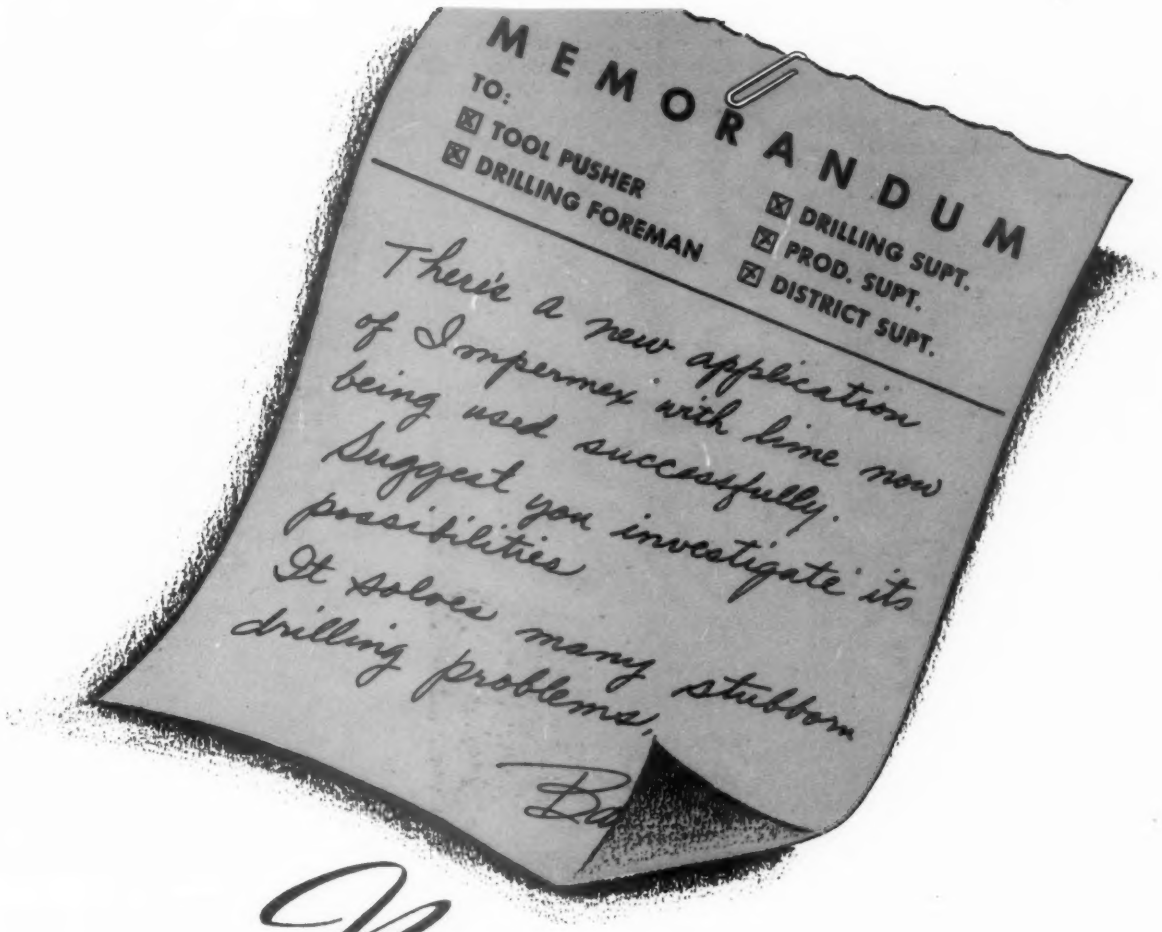
Generally the centralizers are used in combination with scratchers. The centralizers aid in centering the casing, preventing cement channelling and enabling the scratchers to remove the mud cake more effectively as the cement slurry is pumped into position.

As shown in the photograph, B & W Latch-on Centralizers are available with either straight or spiral bows. They are manufactured by B & W Incorporated.



Right—B & W Latch-On Centralizer, spiral-type, mounted on casing coupling. Below—Mounting straight-type centralizer on casing on rack.




MEMORANDUM
TO:
☒ TOOL PUSHER
☒ DRILLING FOREMAN
☒ DRILLING SUPT.
☒ PROD. SUPT.
☒ DISTRICT SUPT.
There's a new application of Impermex with lime now being used successfully. Suggest you investigate its possibilities
It solves many stubborn drilling problems.
Ba

The *New* IMPERMEX-lime Mud provides greater effectiveness with simplified control

This mud is unique because the lime is used in such a manner as to effect a complete conversion of the ordinary drilling clay to a calcium base clay.

In one large field, operators have adopted this type of drilling mud almost entirely for completions. Operators in other districts are beginning to use it for *completions, workovers,* and overcoming contaminants.

This type of IMPERMEX-lime drilling mud presents the following major advantages:

1. Low cost, because of elimination of need for conventional chemical thinners.
2. Low gel strength, because of dehydration of clay by lime.
3. Low water loss, less than 2 cc. A.P.I.
4. Thin filter cake, on the order of 1/32".
5. Freedom from effects of contamination. Salt (in concentrations less than 1%), cement, anhydrite, or gypsum have little effect.
6. No interference with electrical logs.
7. Low density.

Operators using this IMPERMEX-lime mud also find that it will take a lot of rough treatment while requiring little critical maintenance. And it offers no difficult mixing problem.

This IMPERMEX-lime mud differs from conventional IMPERMEX muds which also may use lime. In the new application, operators first prepare a saturated lime-water solution. Next they use this solution as the mixing water for the clay and IMPERMEX.

Possibly your field (or well) will benefit by the use of such a mud. To obtain additional information about this type of mud, please fill out and mail the form below.

BAROID SALES DIVISION
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Los Angeles 54, California

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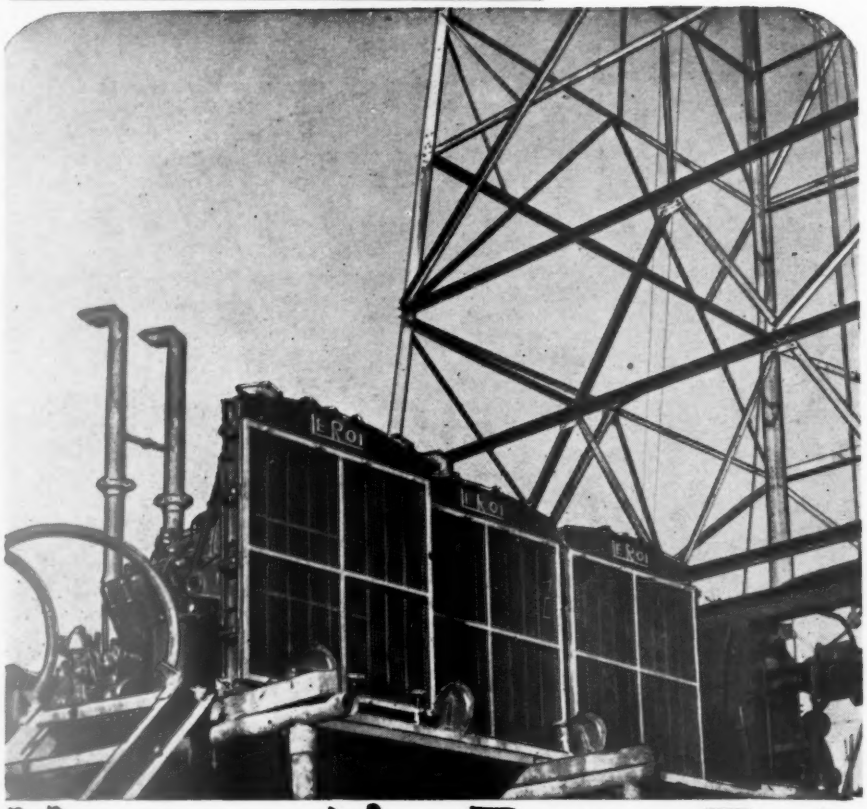

Money-making Footage Feats

...a Le Roi user reports 100,000 feet of drilling with a maintenance cost of $300.00—this is proof of Le Roi stamina

Wherever you go, you find Le Roi making outstanding records for low upkeep. Here are a few more remarks from different drilling contractors:

"For the past four years this engine has been in West Texas and New Mexico where it has furnished power for driving a spudder for drilling sixteen 4000-ft. wells."

"They alone maintain prompt and efficient service, and not once did we shut down a Le Roi drilling engine due to lack of repair parts."

"Without hesitation, we recommend Le Roi as being the best drilling engine available in today's market."

"Although we have operated our RX-1 Le Roi engine almost constantly for the past seven years, we do not think it advisable to trade it in on a new one, as we believe this engine is good for several more years of satisfactory service."

This dependability, backed by the lugging power and rapid acceleration of Le Roi engines, means more footage in less time—and greater profits from your drilling contract. Le Roi engines operate on natural gas, butane, or gasoline. Horsepowers range from 4 to 600. See your Le Roi distributor as soon as you can.

Write for literature.

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Carson Machine and Supply Co.—Great Bend

Illinois — Western Kentucky
Western Machinery Company — Centralia, Illinois and St. Louis, Missouri.

Michigan
Hafer Engine Co. — Reed City

Rocky Mountain Area
Industrial Power Units, Inc. — Casper, Wyoming.

Northern Louisiana & Mississippi
Ingersoll Corporation — Shreveport, Louisiana, and Jackson, Mississippi.

West Coast
Le Roi-Rix Machinery Co. — Los Angeles, Calif.

Appalachian Area
Lloyd, Smith Company — Bradford, Penn.
P. C. McKenzie Co. — Pittsburgh

Canada
Drilling Supplies, Ltd. — Calgary, Alberta

Complete Sales and Service Facilities

P-94

(8) Small tower

A small natural draft cooling tower that embodies the engineering design, balanced spray system, and predetermined performance previously available only in large towers, The Marley Company, Inc. now offers the New Series 100 tower. Several new features are incorporated in the design, as follows:

Lumber fabricated from heavy California heart redwood—all hardware galvanized.

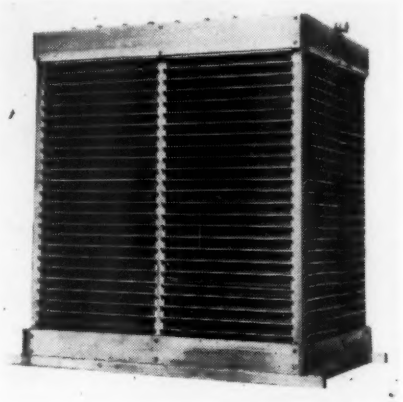
Machined louver posts are without any troublesome nails, bolts, or backup strips.

Louvers are slip-fit and are readily removable for inspection or access to the interior of the tower.

Louvers are respaced and repitched to admit maximum air with minimum drift loss.

Frame and girts are bolted two ways to give maximum strength.

Spray system is designed to give maximum breakup at lowest pressure and to give a balanced spray in all areas in the tower.



Marley patented bronze spray nozzles are selected to give maximum efficiency at the specified gallonage.

Basin is complete with wooden walls and heavy steel basin is complete with automatic float valve and non-cavitating cast-iron suction.

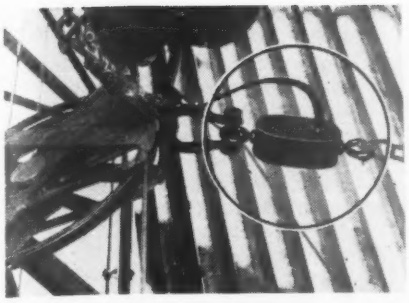
The tower is offered in six frame sizes to give from 4 to 36 tons refrigeration depending on local wet bulb conditions.

Towers are prefabricated and shipped "knocked down" with every member piece marked.

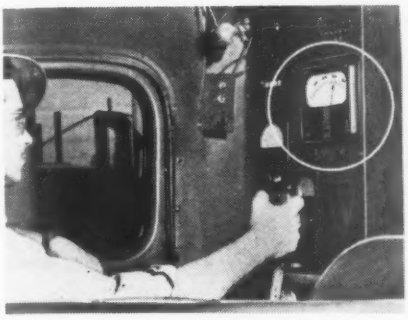
Complete erection, operation, and maintained instructions are provided with each tower.

(9) Weight indicator

A new, supersensitive electronic weight indicator that accurately indicates any minute variation in weight, has been announcd by the McCullough Tool Company. This new weight indicator, through the application of electronics, makes possible the elimination of all wearing parts, the utilization of a smaller and lighter derrick unit, and enables the indicator to detect and locate the following, according to the manufacturer: (1) Fluid level (2) collars; (3) tight places in pipe; (4) liner tops; (5) well bottoms, and (6) any obstruction that may be in the hole.



Smaller and lighter derrick unit is made possible.



Variations in weight are indicated on control panel.

Its supersensitivity also makes it of great value when used in combination with the McCullough gun perforator, Magna-Tector, collar locator or gun tester, pressure bomb, and surface recorder combination, the makers assert.

By attaching collar finder fingers to any tool that is run on a wire line and using the electronic weight indicator in combination with the McCullough sonic unit, the operator is provided with visible as well as sound indication of any variation in weight or speed of travel, permitting a twofold check of well conditions.

The device operates in the following manner:

When run in combination with the McCullough gun perforators, Magna-Tector, collar locator, bridging plug, or surface recording bottom hole pressure bomb and gun tester combination, the weight indicator is placed between the bail of the derrick sheave and one of the tie back chains, as shown in the illustration. An electric conductor cable connects the derrick unit of the weight indicator to the meter in the service truck where the most minute variation of weight is visibly transmitted to the operator.

(10) Improved payloader

The Frank G. Hough Company announces an important improvement in its Model HF ¾ cu yd Payloader tractor shovel. Previously equipped with hydraulic lift and lowering of the bucket, the machine now has the added feature of hydraulic bucket control that dumps and closes the bucket by fingertip actuated hydraulic power. The bucket can be dumped gradually or instantaneously as desired and can be closed immediately by the same hydraulic cylinder. This feature increases the speed and ease of operation because the bucket need not be dropped to ground and tractor re-

PRODUCTION TIPS:

WECO UNIONS COVER THE PRODUCTION FIELD TOO!

For lines around permanent or field storage tanks

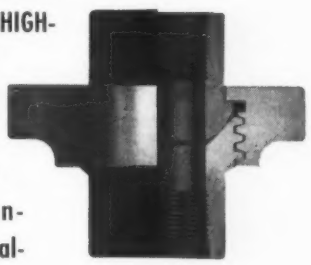
You can bank on WECO's extra strength for dependability up to 10,000 lbs. working pressure.

Tailor-made in size and pressure for any hook-up

Built to withstand temperatures and abrasive or corrosive fluids

Make-up faster, seal perfectly and withstand more abuse

Precision made WECO Wing Unions . . . the original wing union . . . range in sizes from 1" through 10" and in test pressures from 1000 lbs. to 12,000 lbs. In this line-up of proved winners, you will find the WECO Wing Union for any service in the production field. Here's why WECO Wing Unions have set a record for dependability: RUGGED Acme Threads assure speed . . . HIGHEST UNIT BEARING LOAD of any union to give unequaled sealing qualities . . . SELF-ALIGNING to accommodate any practical variance in fabrication . . . EASY MAKE-UP because a blow from an ordinary hammer makes it up or breaks it out . . . THICKER WALLS on sub ends resist distortion and prevent failures. So make your choice of production unions from proved WECO WING UNIONS.



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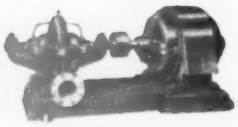
PEERLESS
HORIZONTAL CENTRIFUGAL
PUMPS



TYPE A
Single Stage Pump

FOR CONTINUOUS DUTY GENERAL SERVICE PUMPING PEERLESS TYPE A PUMPS

Capacities: Up to 70,000 G. P. M.
Heads: Up to 300 feet
1 to 1000 H. P. • All Types Drive

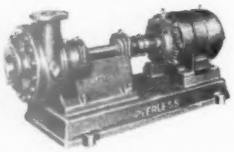
TYPE AF
With Complete Fittings

FOR ADEQUATE FIRE PROTECTION SERVICE TYPE AF FIRE PUMPS*

Underwriters' Approved

Capacities: 500 to 2000 G. P. M.
Pressure: Up to 150 lbs.
20 to 250 H. P.

**Formerly Dayton-Dowd*



TYPE C
Single Stage Pump

FOR ACIDS, CAUSTICS, HOT OILS, CHEMICALS & PROCESS SERVICES... PEERLESS TYPE C PUMPS

Capacities: 10 to 1200 G. P. M.
Heads up to 100 lbs. • 1 to 60 H. P.

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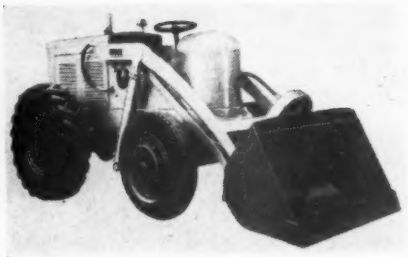


versed to close it. It also relieves the machine and the trucks being loaded of dumping shock and wear and tear.

A new catalog, now available, fully covers this improvement and includes numerous action views showing some of the many earth moving and material handling jobs these rugged, versatile tractor shovels are doing in the public works, construction, mining, and industrial fields.

(11) Hinged connector

One typical connector of its new XTP line replaces up to 32 different parallel or tee connectors, say the manufacturers, O. Z. Electrical Manufacturing Company. Available in 25 sizes, accommodating more than 400 wire combinations ranging from No. 8 to 1,000,000 CM, the XTP will do practically all tap jobs, it is stated. Further, the wide range of the XTP reduces the number of connector types users need carry in stock, it is asserted.

The one-piece, hinged construction of this new connector makes for speed and simplicity in installation. It can be permanently attached to the main and left for the tap to be attached later. One end of the connector is simply snapped over the main and tightened, the other has serrated openings to which a tap can be run in any of three directions.

Other advantageous construction features are: Spring steel lock washers (tin plated) maintain permanent pressure; grip holding serrations on wire-contact surface for maximum pull out strength; non-rotation pressure plates; highly conductive copper alloy body; extra strength copper alloy hinge and pressure plates.

XTP FITTING

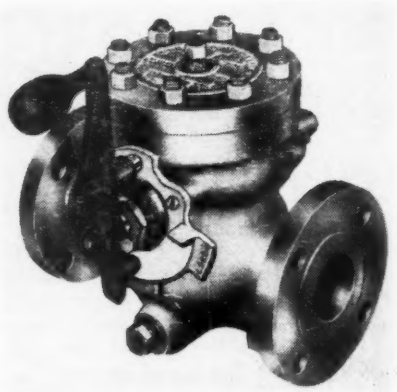
XTP showing hinged construction

XTP as a parallel tap

XTP as a T tap

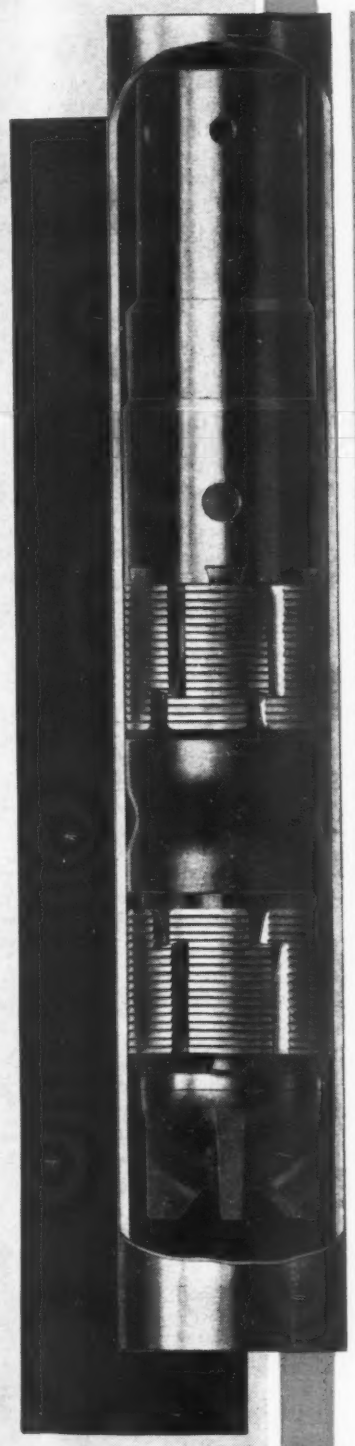
(12) Safety valve

The Daniel safety (back-flow) swing check valve, manufactured by Daniel Orifice Fitting Company, is suitable for a wide variety of services and installations. Primarily it is used to prevent the reversal of flow in horizontal or vertical pipe lines. (In vertical lines, or any angle from horizontal to vertical, they should be used for upward flow only). However, the Daniel valve has gone beyond the simple design of a swing check and several outstanding features have been added. Common installation is on the downstream side of each angle safety or relief valve that discharges individually from each in a group of compressors, pumps, pressure vessels, or storage tanks, such group being piped into a common discharge relief header to carry fumes to atmosphere or to a flare. Whenever an angle safety and relief valve is to be tested or repaired, the flapper of the Daniel valve can be closed by turning lever. The operator may then disassemble the angle valve and repair without any danger of a discharge, or back surge from other angle valves popping. The angle valve may also be tested for leakage by installing gauge (or manometer if angle valve is equipped with test gag) to bottom pipe plug connection on upstream side of Daniel valve seat.



If, when all testing and repair work has been completed, the Daniel valve is, through oversight or negligence, not reset to open position, the line discharge will pass through freely.

SET



LANE-WELLS DRILLABLE BRIDGING PLUGS

★ ON YOUR OWN WIRE LINE
★ OR ON TUBING

WITH

TRIPSET

...the specially designed bridging plug setting tool for oil well operators.

TRIPSET enables the oil well operator to set Lane-Wells Type W Drillable Bridging Plugs on *his own wire line* or on tubing at a substantial saving over the cost of having it set by a Lane-Wells Field Unit and Crew. Purchase of the TRIPSET Tool enables the operator to carry his own stock of Bridging Plugs to be set by his own personnel whenever convenient. In the United States, TRIPSET may be obtained on a service basis and if desired, a Lane-Wells representative will advise on the setting operation.

GET IT! SET IT! FORGET IT — OR DRILL IT!

Tomorrow's Tools - Today!

LANE-WELLS SERVICES available through Petro-Tech Service Co., Maracaibo; Venezuela Oil Field Service Co., Caracas; Trinidad Oil Field Services, Ltd., San Fernando

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trade literature

PUBLICATIONS LISTED ARE SENT FREE UPON REQUEST

(13) Forged steel valves

The Ohio Injector Company announces a new catalog describing its full line of forged steel valves. OIC produces an entire line of 600-lb forged-steel valves in gates, globes, angles, and checks with various types of trim. These are manufactured in screwed, flanged, and socket-weld types. The new catalog describes design and construction, materials, ratings, and markings. Forged-steel gate valves, union bonnet and bolted bonnet; globe and angle valves, inside screw union and bolted bonnet; globe and angle, O.S. and Y union and bolted bonnet; check valves, horizontal; lift union and bolted cap are all described in detail in the 16-page catalog.

(14) Bulletins on oil field equipment

Black, Sivalls and Bryson, Inc., have issued three bulletins, as follows:

"The Phantom Pumper," describing how oil wells can be controlled remotely from a centralized panel.

"Valves For Salt Water Disposal Service," which shows illustrations and specifications of valves for this use.

"Butane-Propane Skid Tanks," used in connection with drilling rigs, pump units, etc.

(15) Fire extinguishing equipment

Pyrene Manufacturing Company has published a bulletin entitled "Carbon Dioxide Type Fire Extinguishing Equipment and Smoke Detecting Systems." The bulletin is well illustrated and shows various types of units, from hand portables up through the large mobile equipment. Descriptions also are given.

(16) Ammonia in petroleum industry

In recent years the applications of ammonia in the petroleum industry have increased greatly, and they will continue to increase as petroleum becomes more important as a starting material for chemical synthesis. The Mathieson Alkali Works (Inc.) has published a booklet entitled "Ammonia in the Petroleum Industry," which discusses the more current applications.

(17) Loading assemblies

Bound inside a tough cover and handsomely printed, Oil Equipment Manufacturing Company, has released its new 32-page catalog, No. 500, a publication that has been two years in preparation. Long recognized for its excellence in designing and manufacturing flexible dome-type truck and tank car loading assemblies, the company emphasizes and illustrates these facilities with great detail in the new catalog. Oilco swing joints, ball joints, and other accessories also are shown. In fact the catalog lists Oilco's complete line.

Although nine types of loading assemblies are illustrated with photographs or diagrammatic drawings, or both, the new Oilco Model 600-A dome-type tank truck loading assembly is one of the standout items in the book. This assembly, already successfully used by many major oil company's stresses the importance of a new type of extension on the valve lever, which regulates oil flow close to the discharge end, without the loss of flexibility in sliding sleeve and dip pipe. The assembly permits quicker and complete loading control, and affords its users numerous other advantages.

Another high spot in this interesting catalog is page 26, which introduces Oilco's perfected self closing line valves. The castings are of tested all-bronze and are equipped with phosphar bronz springs and a special disk that will withstand up to 300 F oil heat. Dual poppet and cam construction permits quick opening and shockless closing of valve. The adjustment screw in the top of the valve enables operator to regulate any pressure up to 125 psi. The valve can be regulated while the line is under pressure, and the device permits maximum volume of flow. The regular models are the hold-open type, but the stay-open type also are available.

(18) Combination starter

"How the High-Interrupting-Capacity Fuses Provide Short Circuit Protection" in a new publication showing construction, operation, and application of "Hi-F use" combination starter for high-voltage induction and synchronous motors for industry. The booklet is issued by Electric Machinery Manufacturing Company.

(19) Cold process water softener

Publication 4425, Cochrane Rapid Reactors, is being distributed by Cochrane Corporation, describing its recently announced cold process softener. Combining the basic elements of equipment for mixing, floc formation, settling, and thickening in a single reaction vessel, the Cochrane Rapid Reactor is used for the conditioning of process cooling water and boiler feed. Chemical reagents may be introduced for coagulation of turbidity alone, for partial softening with coincident turbidity reduction, or for complete softening and turbidity reduction.

(20) Earthmoving equipment

A booklet "Caterpillar Scrapers at Work," devoted exclusively to the problems of earthmoving has recently been published by the Caterpillar Tractor Company. Pictorially and editorially describing the loading, hauling, and spreading jobs done by the "Caterpillar" No. 60, 70, and 80 scrapers packages with the "Caterpillar" Diesel D6, D7, and D8 track-type tractors, the publication should prove of interest to all contractors faced with earthmoving problems.

(21) Process compressors

If you want to get some idea of the variety of sizes and types of air and gas compressors serving the chemical, process, and petroleum industries, send for Ingersoll-Rand's new bulletin, Form 3132, Process Compressors. There are 30 installation pictures with informative captions including the process or general application, horsepower size, pressure, the gas handled, and type of drive.

It shows machines such as a 2500-hp, 7-stage compressor built for 15,000 psi discharge pressure, and 150-hp, 4-stage compressors with non-lubricated cylinders compressing hydrogen to 2500 psi pressure.

In addition the booklet shows the complete line of basic types of I-R compressors and blowers from ½ to 30,000 hp sizes. From these and special cylinders, valves, and coolers, process compressors are built for practically any pressure and any gas.

(22) Trucks in oil field use

Of interest to men in the petroleum producing industries is a new booklet, "Mack in the Oil Fields," issued by Mack Trucks, Inc. Its eight pages are packed with action pictures of Mack trucks at work on oil field hauling jobs of every description. Covering trucks and tractors, four-and six-wheel vehicles, powered by gasoline, diesel and butane fueled engines, the booklet describes and illustrates practically every type of truck and tractor design used in the specialized hauling of oil field material and equipment. Here, under a single cover, is the complete postwar line of Mack trucks specifically designed and produced for these industries.

(23) Consolidated rig

Bulletin 348 describes and fully illustrates the Ideal Type T-25 Consolidated rig, of The National Supply Company, which has a nominal depth rating of 4000 ft using 4½-in. drill pipe with 250-hp input, which may be obtained by using one or two engines. This rig is also well suited for workover jobs to 10,000 ft with 2½-in. tubing with hoisting speed comparable to drilling practice. Because of torque converter in the drawworks transmission, a wide range of engines within horsepower rating, can be used by merely changing the size of the engine drive sprocket. This skid-mounted rig may be moved as a unit with the engine or engines in place. Included in bulletin are specifications, construction details and descriptions of accessory equipment.

(24) Arc metal-cutting tool

Applications of the novel low-cost surface and underwater metal-cutting tool that employs electric arc vapor, known as "CutTrode" are shown in a new illustrated 8-page bulletin pub-

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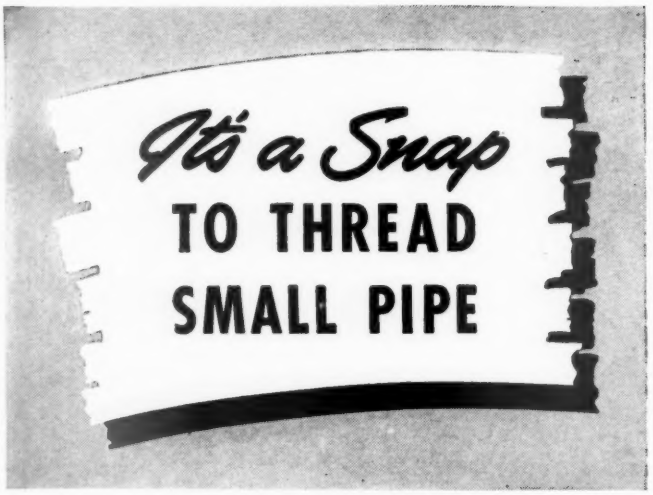

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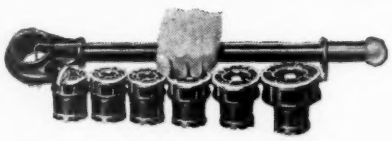

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WORK-SAVER PIPE TOOLS

THE RIDGE TOOL COMPANY • ELYRIA, OHIO

lished by Eutectic Welding Alloys Corporation. Complete information, technical diagrams, instructions for using "Cut-Trode" for large industries and smaller shops are given in detail. Operating hints outlined will aid all metal working men, whether for repair or production metal-cutting.

(25) Resistance welding alloy

Widespread development of resistance welding in the last several years calls for parallel development of alloys used in spot welder tips, electrodes, flash, and projection welding dies and seam welder disks. Acme Electric Welder Company's Alloy Catalog No. 502 depicts a complete new line made from Acmeloy, Superloy, and Stainaloy. New items include a variety of special goose-neck tips, offset tip holders, and seam welder disks, also a complete line of standard tips and holders. Price, specifications and complete stock list of all tips and alloys are included in the catalog.

(26) Illustrated valve catalog

Including more than 70 specially made half-tone photographs, and tables keyed to drawings showing dimensions of valves, a new catalog on the butterfly or disk type valves they produce has been issued by R-S Products Corporation. The volume contains 52 pages and has a particularly easy-to-use index.

(27) Welding guides

The growing use of welded design and thus the greatly increased value of properly indicating welds on drawings have led The Lincoln Electric Company to produce the "Designer's Guide for Welded Construction." This is of such form that it can be placed under a desk glass or thumb-tacked to a drawing board for quick reference.

(28) Slush pumps

National Supply Company's Bulletin 323 describes the Ideal Type C-100 duplex power slush pumps, designed to discharge 380 to 190 gpm at pressures of 520 to 820 psi. The bulletin contains descriptions and illustrations of all main members of the power end and fluid end, including fluid valves and seats, liners, pistons and rods lubrication, including a feature preventing mud contamination of crankcase oil; specifications, performance chart, and drawings with principal dimensions.

(29) Silicone rubber

New and more complete data on all commercially available types of Silastic, the Dow Corning Silicone rubber, are given in Silastic Facts No. 5. Several new types of Silastic are included among the six Silastic pastes and the six Silastic molding and extruding stocks for which typical physical properties including hardness, tensile strength, and elongation are given.

(30) Induction motors

Burke Electric Company has issued a bulletin on its redesigned line of large totally enclosed fan-cooled squirrel cage induction motors. The motors are available in sizes 250 to and including 500 hp for direct driving high speed blowers, pumps, compressors, and like equipment installed under conditions involving dust, abrasives, conducting materials, and/or excessive moisture.

(31) Two-cycle V-angle compressors

The Cooper-Bessemer Corporation has issued a bulletin on its GMW two-cycle, V-angle compressors. This compressor incorporates many of the features of other Cooper-Bessemer "angles" and adds a considerable number of advanced engineering achievements, according to the manufacturers. The GMW, built in 6, 8, and 10-cylinder sizes, is a two-cycle engine with an 18-in. bore and a 20-in. stroke. It develops 240 bhp per cylinder at 250 rpm. For the big compressing jobs in the gas transmission and processing fields, in pressure maintenance and cycling service, or for any stationary application where heavy-duty power is needed, the GMW presents the answer, Cooper-Bessemer officials assert.

(32) Series 71 diesel engines

"Power Parade" is a 12-page pictorial magazine illustrating applications of General Motors Series 71 diesel engines in various business enterprises. Descriptive material follows a narrative form, relating actual performance and operating experi-

ences as reported by product users. Published in three colors on 8½x11 format, the magazine is circulated through the G.M. diesel distributor organization.

(33) Steam and water mixer

A new steam and water mixer to provide hot water at isolated points is described in Catalog 900, issued by Sarco Company, Inc. It eliminates piping of hot water long distances or installing separate heaters in remote places. Takes up little space and delivers hot water at a pre-determined temperature. In 2-colors, the cut-away photographs show operation, installation, and construction. Convenient capacity and dimension tables are included.

(34) Y-type pipe strainers

Bulletin 184, describing ½-in. to 2-in. cast semi-steel Y-type pipe strainers for steam, gas, air, water, and oil lines has been issued by Armstrong Machine Works. The single-sheet bulletin gives detailed information on Y-type strainers with either perforated brass screens or fine mesh woven stainless steel screens.

(35) Improvements in power shovel

Bulletin No. 846-R on the Buckeye Model 70 Clipper power shovel has been released by Gar Wood Industries, Inc. All improvements that have been effected since V-J Day in this Mevac-controlled shovel are shown in the bulletin.

The improved design of the shovel boom provides greater strength without additional weight. A relay valve, added to the dipper trip vacuum chamber, gives more powerful and quicker acting tripping of dipper door. An improved 2-piece clutch band reduces grab or jerk in the swing clutches to a minimum. Band is also easier to replace. A three-cylinder GM Model 3-71 diesel engine with hydraulic coupling, now available as a source of power for the Buckeye Model 70 Shovel, assures smoother operation. Chrysler 8-cylinder gasoline engine is optional equipment.

An entirely new revolving frame has been designed for the tougher excavating problem. The entire trench hoe attachment has been redesigned to give greater strength and increased life on all wearing parts.

(36) Ball-bearing swivel joints

Chiksan Company announces that the new 48-page catalog covering Chiksan ball-bearing swivel joints and fabricated products is now available. A feature of this new catalog is the introduction of a color code for easy identification of each type of swivel joint according to its pressure capacity. Cutaway views are used to show the design and construction of basic types and packing units are fully illustrated and described. Weights and dimensions are shown for all joints. Complete instructions for servicing and lubrication are also included. Specifications include kinds of materials used in the construction of each type of swivel joint, such as malleable iron, bronze, aluminum, steel castings, and forgings. Pressure capacities range from 125 psi to 12,000 psi in eight different styles of joints with full 360 deg rotation in 1, 2, and 3 planes.

(37) Water treatment and mud

Of real interest to petroleum engineers, drillers, and others concerned with mud problems, is a booklet published by Page Laboratories, dealing with the effect of water treatment on mud condition. The book makes it clear that just plain soft water is not the requirement for the preparation of effective mud. There are certain salts in most natural waters that might be used for make-up that, in the right proportion, have a beneficial effect on the stability and other desirable characteristics of drilling mud. Practical field applications of a compound especially developed for the treatment of make-up water are detailed in the booklet, and it carries a full discussion of the various considerations involved in effective mud operations.

(38) Multi-circuit unit substations

Allis-Chalmers multi-circuit unit substations and their economy, safety, and adaptability features are covered in a new 16-page bulletin released by the company. The new bulletin describes construction details of three transformer types—oil-filled, "Chlorextol" liquid-filled and dry-type. Also described are construction highlights of the load ratio equipment and the metal-clad switchgear. It is available with magnetic, air blast, and oil circuit breakers.

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● You needn't be afraid of thinning, flaring or splitting pipe or conduit when you use a RIDGID extra-long-taper reamer. Even when hurried, the long-taper design lets you whisk out burr safely . . . with a few easy ratchet strokes. You save pipe and time with this efficient work-saver tool. Especially adapted for reaming with RIDGID Porta-Power or other power drives.

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running tour with men in the industry

● **A. Paul Callahan** recently joined Sohio Petroleum Company as petroleum engineer for the West Edmond Hunton line unitization project. Sohio is the unit operator. Before this, Callahan was The Texas Company district engineer for their Drumright and Seminole districts. He has been active in the petroleum fields of the Mid-Continent area since 1932.

● **Claig H. Perry,** Tulsa, Oklahoma, has been made secretary and manager of the gas division for the recently organized Texas Natural Gasoline Corporation, an affiliate of Edwin B. Cox & Jake L. Hamon, independent producers of Dallas, Texas. Perry recently resigned from Warren Petroleum Corporation, Tulsa, Oklahoma, to accept his new position. At the time of his resignation, he was gas engineer in charge of all exploration work in connection with locations of new plants.

Claig H. Perry

● **W. C. MacMillan** has been elected president of Texon Oil and Land Company, Group No. 1 Oil Corporation, and Group No. 2 Oil Corporation, non-consolidated affiliates of Continental Oil Company. Simultaneous announcement was made of the election of **E. J. Sheldon,** Ponca City, as a director of Texon Oil and Land Company. Other members of the Texon directorate are **James J. Cosgrove, R. L. Bosworth, Charles A. Perlitz, Jr.,** and **P. L. Arrington.**

Texon and its subsidiaries own production, leaseholds, and royalty in a large number of fields in Oklahoma, Texas, and Kansas.

● **G. N. Frost,** former field salesman for The Continental Supply Company at Brookhaven, Mississippi, has been appointed store manager at the same location, succeeding **J. R. Osteen.** The latter has been transferred to Shreveport as store manager. **Guy W. Bigham,** Continental's former store manager at Shreveport, has been transferred to Shreveport district office as district sales representative.

● **C. E. Finney, Jr.,** has been advanced to the presidency of the Salt Lake Refining Company and the Salt Lake Pipe Line Company, subsidiaries of Standard of California, it has been announced by T. S. Petersen, president of Standard. Finney has been a vice president of Standard. In his new position, Finney will direct the construction and operation of both projects. Each will cost approximately $5,000,000 and they are scheduled to be completed and in operation by November 1, 1948.

● **Daniel J. Moran,** former president of Continental Oil Company, died April 3 in Houston, Texas, after a long illness. He was 59 years of age.

Daniel J. Moran

Starting early in the oil business, Moran was a messenger for a pipe line company at the age of ten. He received his degree in mechanical engineering from the Case School of Applied Science at Cleveland, Ohio. Moving to Tulsa shortly thereafter, he became designing engineer for the Oklahoma Iron Works, now Bethlehem Supply Company. In 1912 he went to Port Arthur, Texas, for The Texas Company to engineer construction of its refinery and terminal there. He remained with The Texas Company and rose to vice president and general manager.

He became president of Marland Oil Company in 1929, about the time Marland and Continental Oil Company of Denver were merged. From this merger was built the Continental Oil Company. Moran retired from the presidency of Continental the fall of 1947.

● **Dr. Nelson H. Darton,** eminent geologist, died recently at his home in Maryland at the age of 82. Darton prepared USGS maps of more than a million square miles of territory, including base maps for many areas and countries.

● **Dr. H. G. Burks, Jr.,** a director of Esso Standard Oil Company, has been named general manager of the company's manufacturing operations. **H. W. Fisher,** also a director, was named to succeed Dr. Burks as general manager of East Coast refineries. Both men, whose entire business careers have been with the company, joined Esso on graduation from the Massachusetts Institute of Technology more than 20 years ago.

H. W. Fisher

H. G. Burks, Jr.

● **George Kelso,** manager of the Technical Service and Plant Operations Division of the Houdry Process Corporation, has resigned to become associated with **V. L. Sanderson.** They will act as sales engineers of equipment for the petroleum and chemical industries in the Philadelphia area.

● **Harold Smith,** service representative of the Franks Manufacturing Corporation, Tulsa, Oklahoma, flew to the Veracruz region of Mexico where he will instruct a drilling crew in the operation of a Franks SAL 5000 drilling rig. Marshall & Smith, Artesia, New Mexico, drilling contractors, recently purchased the unit from Franks. The rig is to be used in deep exploratory work.

● **Van D. Bennett,** petroleum consultant, Houston, Texas, has changed his address to 532 Esperson Building.

● **L. A. Boyd,** Tulsa, Oklahoma, has been appointed chief engineer and general superintendent of plants for the recently organized Texas Natural Gasoline Corporation, an affiliate of Edwin B. Cox & Jake L. Hamon, independent producers of Dallas, Texas, it has been announced by John T. Oxley, president. Boyd recently resigned as chief engineer for Warren Petroleum Corporation, Tulsa, Oklahoma, to accept his new position. He had been with the Warren organization since 1940.

L. A. Boyd

● **G. T. Buskirk** has been made division geologist and in charge of Stanolind Oil and Gas Company's exploration office in Bogota, Colombia, C. T. Jones, manager of foreign exploration, has announced. Buskirk will have a six-man staff of Stanolind men transferred from this country and will hire additional employes in Bogota. Buskirk, formerly district geologist at San Antonio, Texas, will have the following people working with him:

J. A. Thompson, office manager, formerly an assistant section head in the accounting department, Tulsa office.

J. H. Chivers, geologist, formerly geologist in the Casper, Wyoming, office.

J. W. Vanderbeek, geologist, formerly geological scout at Wichita Falls, Texas.

W. A. Sidwell, landman, formerly landman at Houston, Texas.

Jack Hunter, geological scout, who received his master's degree in geology from the University of Texas in February, 1948.

Frank Crespo, clerk, formerly in the land department, Tulsa general office.

Jones also announced the following additions to Stanolind's Canadian division, Calgary, Alberta:

W. B. Longshore, senior landman, formerly landman at Casper, Wyoming.

R. W. Craig, senior geologist, formerly geologist at Lake Charles, Louisiana.

T. B. Hewitt, landman, formerly a senior clerk at Jackson, Mississippi.

J. H. Helland, geological scout, formerly in the San Antonio, Texas, office.

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Corpus Christi	Oklahoma City	Hobbs	Bakersfield	New Iberia
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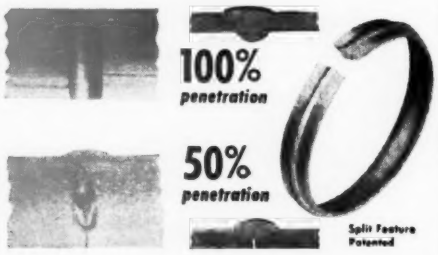

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SAVE MONEY

● **W. W. Davison** has been appointed a vice president of Standard Oil Company of California. Davison has been general manager of Standard's El Segundo Refinery. He joined Standard in 1921 as junior engineer.

● **William H. Schuster** has been appointed welding supervisor of the American Car and Foundry Company. He was first employed by Spang Chalfant and Company as welder from 1931 to 1935 and the following year with the Bath Iron Works in the same capacity. He then went to Lincoln Electric Company as welding instructor and from 1937 to 1940 was sales engineer for that company. From 1940 to 1946 he was general welding supervisor for Cramp Shipbuilding Company. Prior to joining ACF he was with Foster Wheeler Corporation as welding engineer.

W. H. Schuster

● **William F. Scott, Jr.,** has been named manager of the Oil Well Supply Company store at Bolivar, New York, succeeding **E. W. Rice,** retired. Scott, who served with the U. S. Infantry in the recent war, joined "Oilwell" in October, 1945, as a storeman in the Bolivar store. Since October, 1947, he has held a similar position at the company's Bradford, Pennsylvania, store.

● **J. C. Denney,** former civil engineer of the North Government Wells district, Southwest Texas Division, Humble Oil and Refining Company's Production Department, is now district civil engineer. **L. H. Byrd,** district petroleum engineer of the Hawkins district, East Texas division, was promoted to assistant district superintendent of the London district.

W. B. Ewing and **C. N. Hunt** have been transferred from the London district, East Texas division. Ewing has been promoted from assistant district superintendent to district superintendent at Pruitt. Hunt, former farm boss, is now assistant district superintendent of the Wink district, West Texas division.

C. E. Stanley, district superintendent, has been transferred from the Pruitt district, East Texas division, to the Thompsons district, Gulf Coast division. **H. W. Roberson,** formerly district superintendent of the Navarro Crossing district, East Texas division, is now in the same capacity with a Gulf Coast division district to be announced later.

C. M. Boatman, farm boss, has been promoted from the McCamey district to assistant district superintendent in the Hobbs district, West Texas division. Also promoted to assistant district superintendent, **C. C. McNeil,** former farm boss in the Wink district, is now at the Wasson district, West Texas division. **P. M. McFadden,** assistant district superintendent, formerly of the Hobbs district, is now in the McCamey district, West Texas division.

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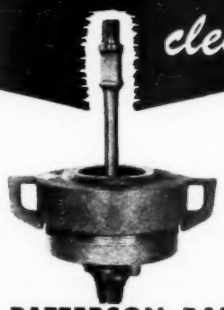

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● W. F. **Rockwell, Jr.,** president of Rockwell Manufacturing Company, has been elected to the board of directors of the Pennsylvania State Chamber of Commerce. Rockwell also has been appointed to the Legislative Advisory Sub-committee for the World Trade Council as sponsored by the Chamber of Commerce. Pittsburgh, Pennsylvania.

● **Al Moon,** lubricator division representative in the oil fields for McCord Corporation, Detroit, is now at 310 Thompson Building, Tulsa, Oklahoma. Moon's 20 years' experience in the engineering department with the McCord Corporation is available to users of mechanical force feed lubricators and chemical pumps, it is announced.

Al Moon

● **Don M. Mattocks** has been elected secretary of Warren Petroleum Corporation and its subsidaries. He succeeds **John T. Oxley** who has resigned. In his new capacity Mattocks will head a department that will correlate many of the activities resulting from the expanded scope of operations of the Warren organization. Since the acquisition by Warren of the Hanlon properties in 1946, he has been first assistant to Jams E. Allison, vice president and general counsel.

Don M. Mattocks

● **A. W. Baucum** has been named assistant to the manager, producing department. The Texas Company, and three other personnel changes in the department have been announced. Baucum, who is assistant division manager, South Texas division, was employed by The Texas Company as a roustabout at Freer, Texas, in 1934. After working as junior petroleum engineer at Jennings Ranch field and, later at Pierce in charge of field engineering work, he was transferred to the South Texas division office in Houston in 1938 and served in various petroleum engineering assignments. He was appointed division petroleum engineer of the Oklahoma-Kansas division at Tulsa in April, 1944. Baucum was named to his present position, October 1, 1946.

George H. Clark, division geologist, South Texas division, since February, 1947, becomes acting assistant division manager.

S. A. Berthiaume has been advanced from geologist to acting division geologist as a result of Clark's transfer.

It was also announced that **C. F. Redmond, Jr.,** petroleum engineer in West Texas division, producing department, has been transferred to the office of the manager, at Houston to work on the staff of **E. P. Hayes,** chief petroleum engineer.

● **Ted Forsyth** lost his wife Saturday, April 3. She passed away at St. Francis Hospital, Lynwood, California. Funeral services were held April 6 in St. Mathias Church, Huntington Park.

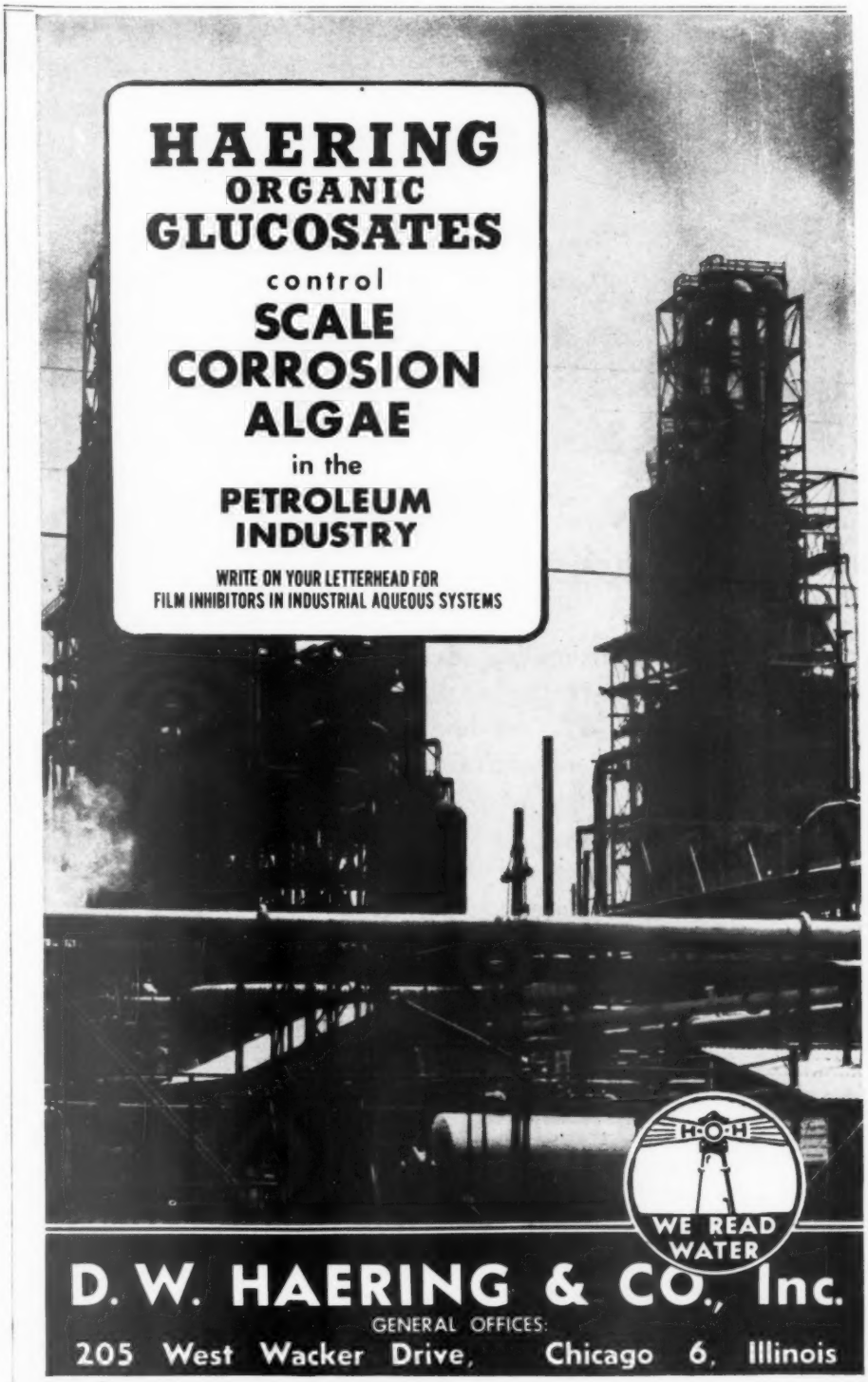
Forsyth is export and domestic sales manager at Los Angeles for Emsco.

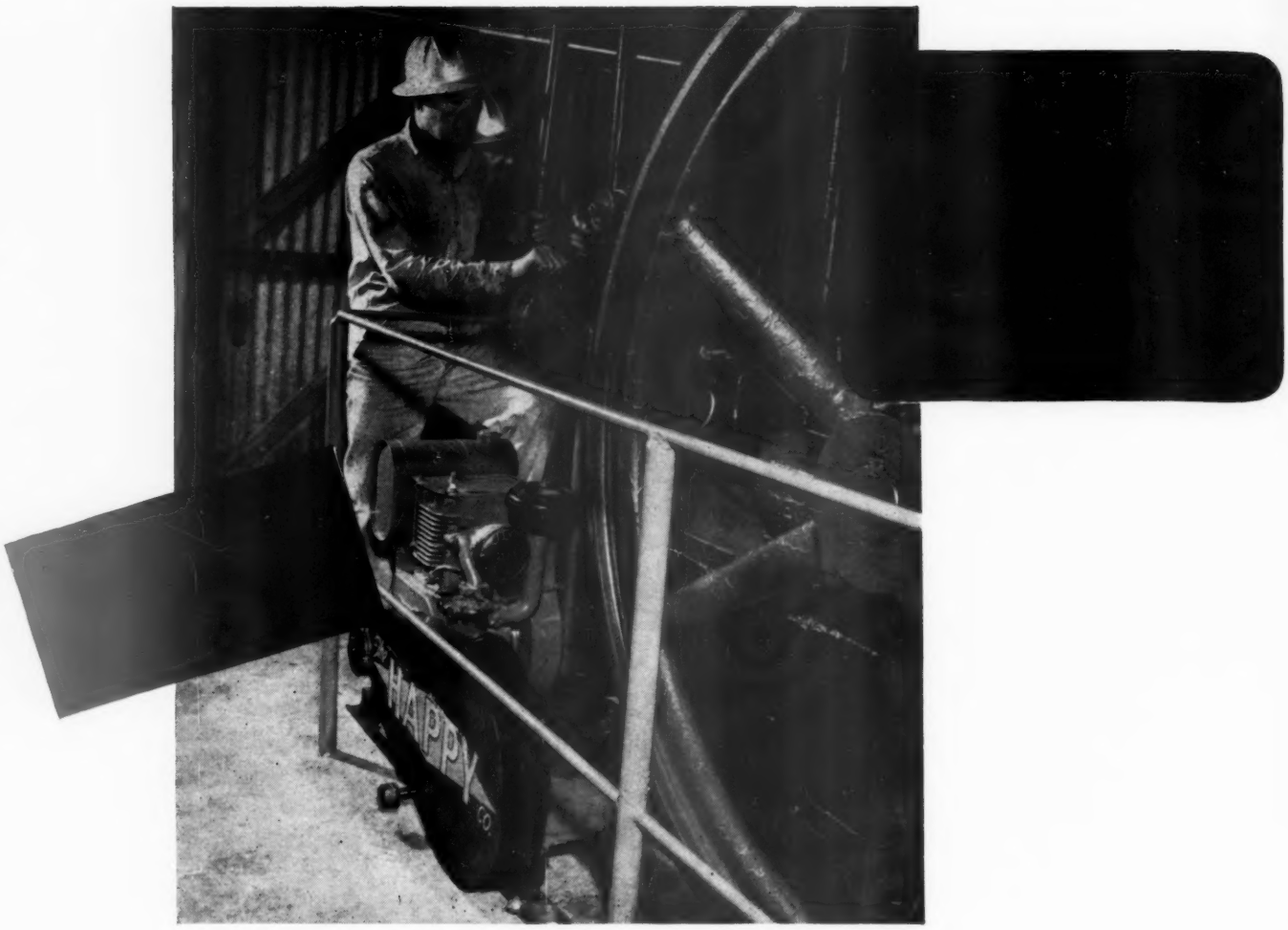
● **L. J. Fulton** has been appointed assistant to the division manager in charge of exploration of the Rocky Mountain Producing Division of The Pure Oil Company. Before being appointed to his present position he was chief geologist of the same division.

K. Stewart Cronin has been made chief geologist of the Rocky Mountain Division. He joined the geological staff of the Gulf Coast Division of The Pure Oil Company at Houston, Texas, in 1933, and has been with the Rocky Mountain Producing Division since 1945.

Robert A. Fellows has been appointed to the position of division development geologist. Fellows joined The Pure Oil Company geological staff, Illinois Division, in October, 1937, and was transferred to the Rocky Mountain Producing Division in 1943.

● **G. R. Brainard, Jr.,** resigned his position as district superintendent with Shell Oil Company, Hobbs, New Mexico, on April 1, to become assistant division superintendent of drilling and production for the Mid-Continent Division, Seaboard Oil Company of Delaware, with headquarters in Dallas, Texas.





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This index will be revised monthly. The index for installments 1-12, inclusive, will be found in the May, 1938, issue; 13-24, inclusive, in the June, 1939, issue; 25-36, inclusive, in the June, 1940, issue; 37-48, inclusive, in the June, 1941, issue; 48-60, inclusive, in the June, 1942, issue; 61-72, inclusive, in the June, 1943, issue; 73-79, inclusive, in the January, 1944, issue; 80-82, inclusive, in the April, 1944 issue; 83-85, inclusive, in the July, 1944, issue; 86-88, inclusive, in the October, 1944, issue; 89-91, inclusive, in the January, 1945, issue; 92-94, inclusive, in the April, 1945, issue; 95-97, inclusive, in the July, 1945, issue; 98-100, inclusive, in the October, 1945, issue; 101-103, inclusive, in the January, 1946, issue; 104-106, inclusive, in the April, 1946, issue; 107-109, inclusive, in the July, 1946, issue; 110-112, inclusive, in the October, 1946, issue; 113-115, inclusive, in the January, 1947, issue; 116-118, inclusive, in the April, 1947, isisue; 119-121, inclusive, in the July, 1947, issue; 122-124, inclusive, in the October, 1947, issue; 125-127, inclusive, in the January, 1948, issue.

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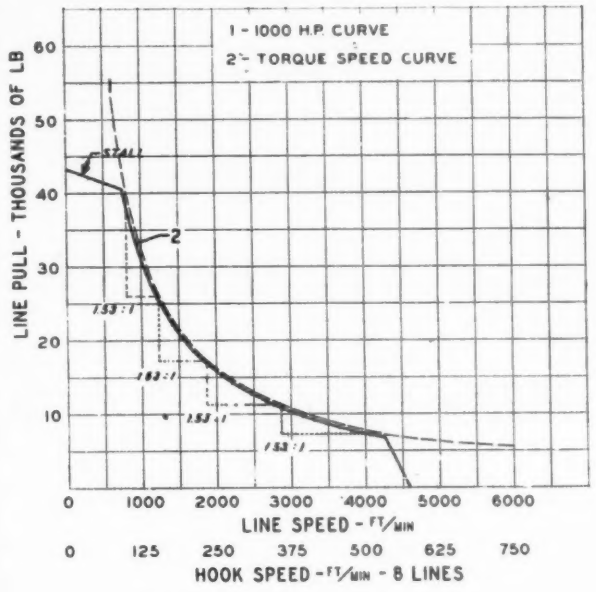


FIG. 5. Electrical 4 speed curves.

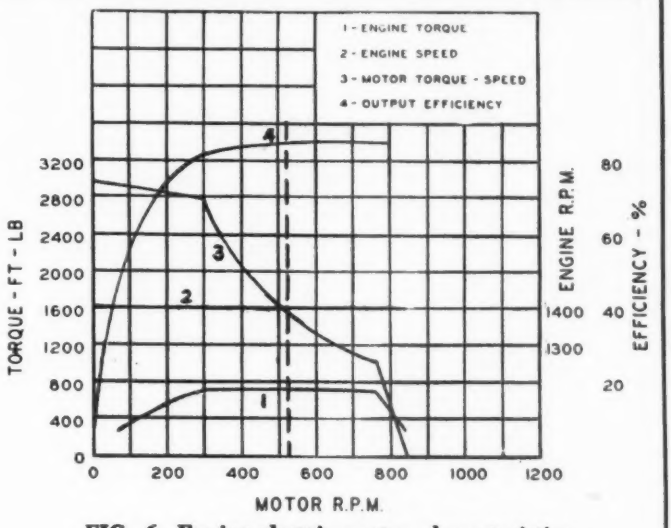


FIG. 6. Engine-electric motor characteristics.

A. Mechanical. As is well known, mechanical transmissions give output torque characteristics that are, neglecting friction, in direct proportion to engine characteristics. Speed changes on decreasing loads are made after the engine reaches maximum governed speed and when engine loading has become reduced below the maximum by an amount inversely proportional to the next increase of speed ratio. When the speed ratio is decreased, the engine is once again loaded to full load at full speed and again falls off, step by step, as the load falls off. If, as is generally the case, the speed is changed too soon, the torque pulls the engine speed down toward peak torque speed of the engine, resulting in very slightly more torque but a greatly reduced speed. This gives a considerably reduced horsepower input to the machine. In either case, the engine reaches full horsepower at full speed at only one point of the load for each speed.

Fig. 4* illustrates the speed torque characteristic of a mechanically driven drilling hoist that has, for the sake of illustration, a 1000-hp maximum hook horsepower. It will be noticed that, in order to reach the peak pulling torque and speed necessary for the class of hoist chosen, it is necessary to employ six speed steps.

The main load steps chosen are equal load steps with a special ratio step shown on each end to obtain the high peak speeds and torque necessary for full performance.

The shaded areas under the curve represent loss of applied horsepower to the load because of the necessity to reduce engine speed, or load, to conform to the gear ratios. A greater number of speeds, naturally, would reduce the area of the losses.

†See sheet 2, P 422.34.

All mechanical hoists use friction clutches for coupling the engines to the load. In some cases, hydraulic couplings are also employed to absorb torque shock loads. Hydraulic clutches are seldom used for actually coupling the loads because of the extreme variations in speeds required from a drilling hoist and the low efficiency of hydraulic couplings at low speeds.

The best of modern hoists employ friction clutches to a large degree for speed changes as well as for load coupling. Accelerating of loads is almost invariably performed by coupling the loads at reduced engine speeds and accelerating engines and load together.

B. Electrical. In this discussion, no account will be taken of a-c power for drilling rigs because of the relatively poor characteristics of a-c for hoisting and the fact that central station power is seldom available for drilling services. Generation of alternating current on the site in a rig power plant is impractical and undesirable unless under highly specialized circumstances. The discussion, therefore, concerns only d-c power applications of the basic Ward Leonard type. This type of power has proved ideal throughout industry for all types of hoisting and transportation involving heavy accelerations, high peak loads of short duration, and variable speed loads.

Fig. 5 shows a speed torque curve of the 1000 hp exemplary hoist load, using d-c motors. As can be noticed, the main speed steps are identical with the mechanical hoist example in Fig. 4,† but the low and high gears are omitted and unnecessary. This, therefore, calls for only four speeds instead of six to give the total load-speed range required.

*See sheet 2, P 422.34.

It can be seen that the power produced by the motor drive is almost identical with a true mean horsepower curve. This is due to the fact that, being electrically coupled to the load, the engines can run at full speed and produce full horsepower for each step of the load, as long as the driving motors can withstand the torque (or current) demand of the load.

Fig. 6 gives a composite set of engine to motor shaft curves, which are interesting when compared directly with those in Fig 8.‡

The chief advantages of electric motor drive over direct mechanical drive are:

(a) Starting torques up to 225 per cent (115 per cent for mechanical).

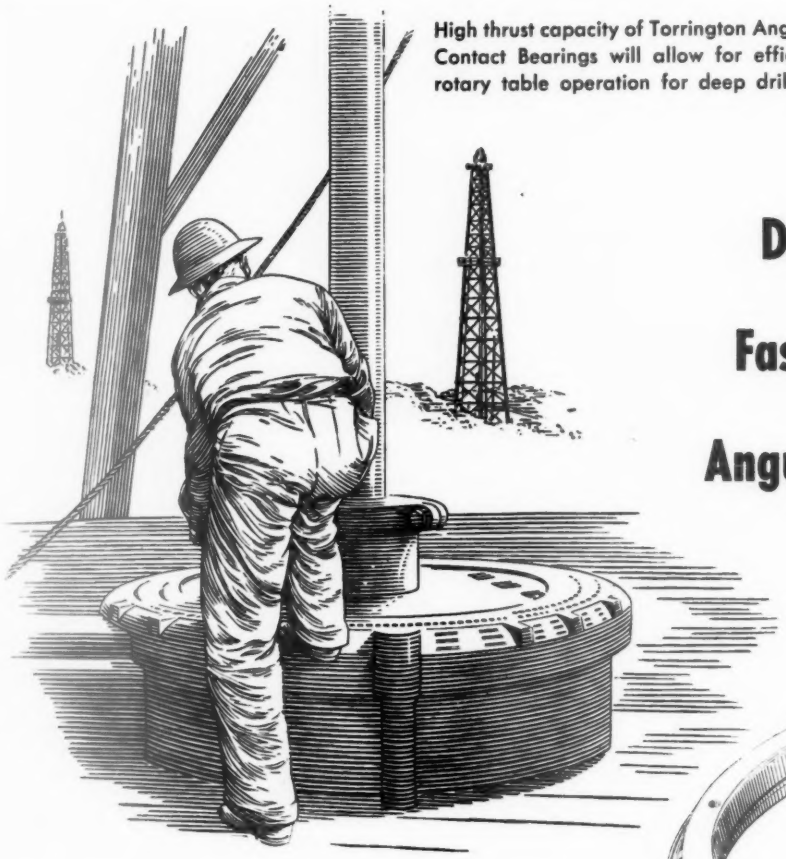
(b) Electrical load coupling involves no slipping clutches or wearing out of mechanical parts — can stall at any load up to full load, indefinitely.

(c) Engines can deliver full horsepower to motors at any speed at which latter can absorb it.

It should be remembered that, except for almost instantaneous peak torque available over the accelerating period, the electric motor itself does not incorporate speed ratio changes. It is essentially a high starting torque device, with full torque almost instantly obtainable at any speed up to full speed. By using oversize motors and generators, high current capacities are usable at the same horsepower engine output, thus giving the effect of torque multiplication.

‡See sheet 4, P 422.34.

Taken from the article, "Application of internal-combustion engine power to rotary drilling rigs, by W. S. Crake, Shell Petroleum Company. Presented before The American Society of Mechanical Engineers, Houston, Texas, October 5-8, 1947, and published in *The Petroleum Engineer*, December, 1947, pages 70 to 80, inclusive.



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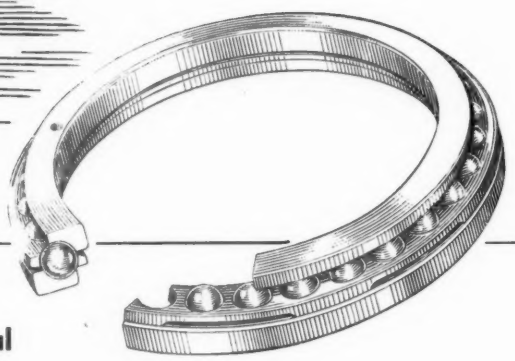

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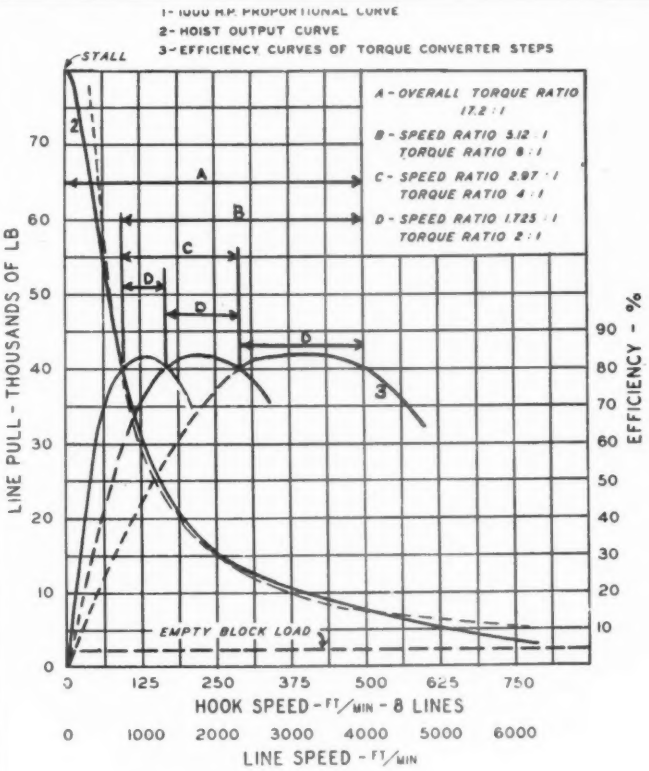
1- 1000 H.P. PROPORTIONAL CURVE
2- HOIST OUTPUT CURVE
3- EFFICIENCY CURVES OF TORQUE CONVERTER STEPS
STALL
A - OVERALL TORQUE RATIO 17.2 : 1
B - SPEED RATIO 5.12 : 1 TORQUE RATIO 8 : 1
C - SPEED RATIO 2.97 : 1 TORQUE RATIO 4 : 1
D - SPEED RATIO 1.725 : 1 TORQUE RATIO 2 : 1
EMPTY BLOCK LOAD
LINE PULL - THOUSANDS OF LB
EFFICIENCY - %
HOOK SPEED - FT/MIN - 8 LINES
LINE SPEED - FT/MIN

FIG. 7. Hydraulic 3 speed hoist.

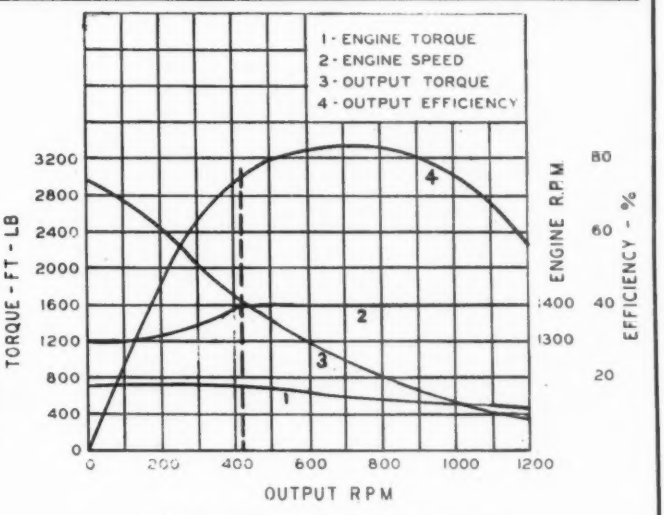

FIG. 8. Torque converter curves.

C. Hydraulic. Fig. 7 shows the application of a hydraulic torque converter to our 1000-hp hook load, and an inspection of the speed torque characteristics shows it to be practically ideal. The shaded area in this case shows a slight gain over the theoretical 100 per cent or ideal curve, because the torque converter increases in efficiency slightly over the portion of its speed range used. In this specific case, only three speeds are required in the hoists to give an ideal curve.

Fig. 8 shows a well known set of specific curves of engine to output shaft performance, which requires little explanation.

The torque converter, when used over its efficient range, is the only device that, in itself, produces a speed ratio change, allowing the engine to run at full horsepower at full speed and deliver full horsepower at a reduced speed to the delivery shaft. For this reason, it has the most ideal characteristics of all known methods for variable load hoisting operations.

The load accelerating characteristics are not as good as the d-c electric, but the load coupling is almost identical and about as trouble free—no moving mechanical parts being in the friction circuit.

D. Effect on hoist design. As seen from a study of Figs. 4, 5, and 7, either a six, four, or three-speed hoist is required for efficient usage. Any variations in these requirements would mean waste of expenditure for more than the requirements, or failure to perform adequately for less than the requirements. Even the distance between steps of speed changes is sufficiently different to make one machine unsuitable to cover all three methods efficiently.

The hydraulic drive, if placed on the engine shafts of multi-engined rigs, places the torque multiplication ahead of the engine coupling transmissions, which correspondingly requires making them capable of up to five times their normal torque rating. This is clearly expensive and undesirable and, therefore, the torque multiplication device belongs in the hoist for greatest economy.

In effect, and for greatest adaptability of hoists to the three transmission methods, the compromise appears to call for a basic two-speed hoist using a two-speed auxiliary transmission for electrical or hydraulic drive, or a three-speed for mechanical drive. For somewhat deeper drilling, this might require a two-speed auxiliary for hydraulic drive, three-speed for electric, and four-speed for mechanical. For shallower drilling, a single-speed basic hoist would suffice, with a two-speed hydraulic, three-speed electrical, and four or five-speed mechanical auxiliary transmission being used.

E. Rotary drives. The mechanical gear change for rotary drives must be handled cautiously to avoid excessive torque loading of drill pipe and, in any case, should never be operated on the engine governor, for this device would merely open up as load increased and place full engine torque on the input end of the gear train, with unfortunate results to the drill pipe.

The same applies to the torque converter, which can, at any point of engine throttle setting, multiply the set torque by about five, unknown to the operator, unless it is provided with automatic torque limiting devices.

Electrically, the motor can simply be set to any desired stalling torque (or current), and provides the safest method of preventing excessive overload. This drive has infinitely variable speed from zero to full speed.

F. Emergency or standby drives. The torque converter provides the most ideal method of providing for emergency hoisting service in case of breakdown of the main equipment. In such cases, the efficiency of the drive is not nearly as important as a high range of operating torque, for which this device is best adapted. Normally, an emergency hoisting unit needs to be only 10-20 per cent of the main hoisting engine so as to get the operator out of major trouble in case of breakdown of the main unit.

G. Pump drives. The slush pump is essentially designed as a constant torque piece of equipment and torque multiplication is undesirable for pump drives. Any increase of torque beyond design loading cannot be carried by the pump for long periods of time. Increased pressure capacity must be obtained by reducing liner sizes.

Taken from the article, "Application of Internal-Combustion Engine Power to Rotary Drilling Rigs," by W. S. Crake, Shell Petroleum Company. Presented before The American Society of Mechanical Engineers, Houston, Texas, October 5-8, 1947, and published in *The Petroleum Engineer*, December, 1947, pages 70 to 80, inclusive.

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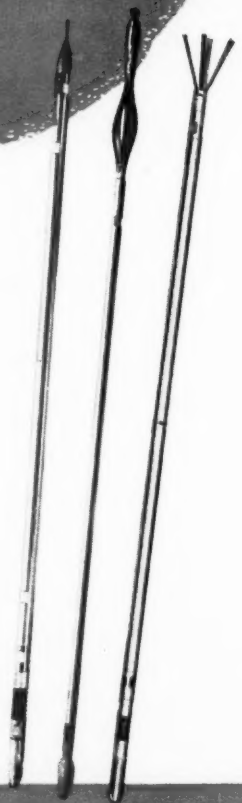

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DESIGN LIMITATIONS AND PERFORMANCE CHARACTERISTIC OF ROCK BITS

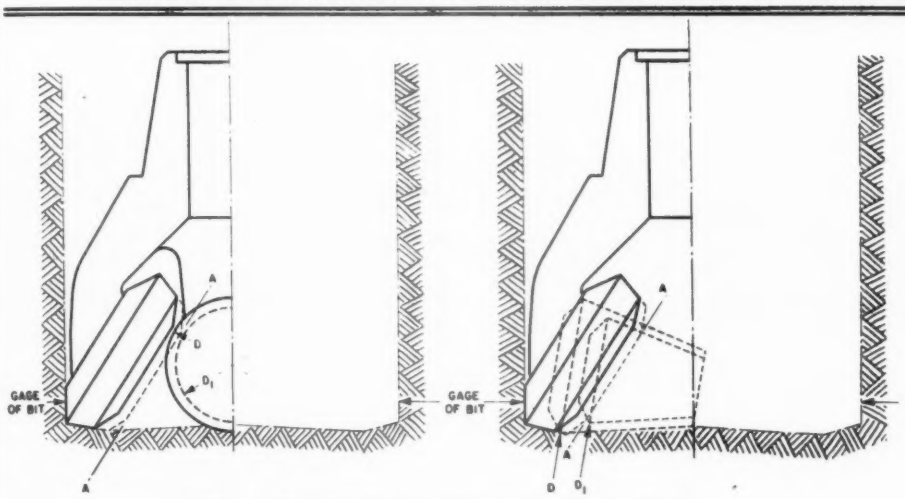

FIG. 1. Clearance between cutters of a rock bit.

The fundamental and most confining of all considerations in the design of any rock bit is simply one of space or room. It must be kept in mind that in the design of a rock bit, every part of the bit that digs the hole must be contained inside the diameter of the hole. This merely means that every element of a rock bit that digs an 8¾-in. hole must be inside an 8¾-in. diam circle. For example, if a larger diameter cutter is indicated, this change can be accomplished only by compromise with other parts in the bit. Space consideration can more clearly be seen by looking at Fig. 1, in which is illustrated the clearance between cutters of a bit. It is evident that if the outside cutter is made wider by moving its inside face over to the dotted line "A-A," that the radius of the second cutter must be made smaller a corresponding amount, this being shown by the dotted circle of diameter "D_1." This condition would favor the outside cutter considerably, for a greater roller bearing capacity could be placed under it, and the second cutter would be weakened to the danger point. It might occur to some of you that the outside cutter could be made larger in diameter, as illustrated in Fig. 2. This could be done; but here again trouble would result. The outside cutter would contact the wall of the hole in two spots causing early and premature wear. Further, the excessive diameter would cause cramping of the outside cutter bearings and quick failure would result. From these two figures it immediately becomes apparent that the design of a rock bit is one of intricate balance between the diameters, lengths, and angles of the axes of the cutters.

The consideration of space is not only important in the geometry of the bit, but is important with respect to the inside construction of the bit; that is, the parts you never see, such as shell thickness, bearing diameter, and journal diameter. This is shown in Fig. 3, in which

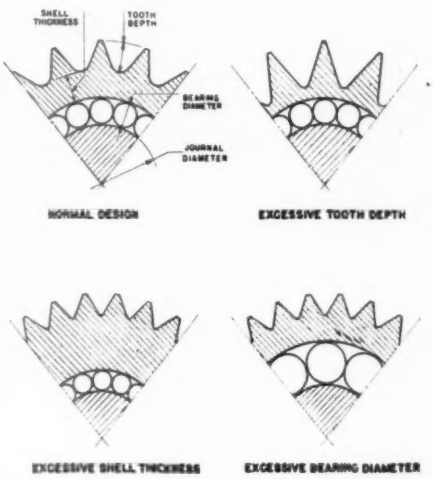

FIG. 3 Effect of excessive tooth depth, shell thickness, and bearing diameter on rock bit cutter design.

several examples are illustrated showing an enlarged view of the sections taken through various cutters. In the design of a cutter of a specific diameter, the designer is faced with four considerations; namely, tooth depth. shell thickness, bearing diameter, and journal diameter. Here again the designer is faced with the problem of spacing or balancing. It clearly can be seen that if he favored the teeth by making them very deep, he reduces the shell thickness, bearing diameter, or journal diamter. If he favors shell thickness, he does so at the expense of one or all of the other three elements; or, if he favors bearing diameter, then he still penalizes one or all three of the other elements. This figure serves to illustrate that the designer must have the proper balance between tooth depth, shell thickness, bearing diameter, and journal diameter, in order to arrive at a bit that gives you the maximum bit life.

Once the designer has completed his work on the drawing board and has what he considers to be the best balanced design from which to build a bit, he is then faced with the problem of materials.

We have discussed only two considerations which affect the design of the bit and the materials to be used in it but there are many more. The designer must be constantly aware of such conditions as are listed in Fig. 4.

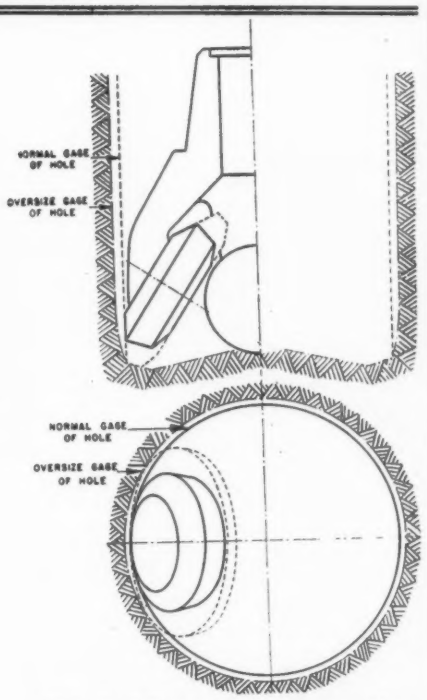

FIG. 2. Effect of oversize outside cutter diameter on size of hole.

1. Space requirements.
2. Materials.
3. Tooth design.
4. Hard metal—selection and application.
5. Bearings.
6. Tolerances.
7. Surface finish of working parts.
8. Frame of bit forgings, castings, weldments, etc.
9. Nozzle assembly.

FIG. 4 Fundamental considerations for rock bit design.

Taken from the article by Wiley B. Noble that was presented before American Association of Oilwell Drilling Contractors, Long Beach, California, October 13-15, 1947, under the full title of "Fundamental Considerations in the Design of Rock Bits with a Discussion of Laboratory Data on Effect of Weight and Rotary RPM on the Drilling Efficiency of a Rock Bit," published in *The Petroleum Engineer*, November, 1947, pages 141 to 146, inclusive.

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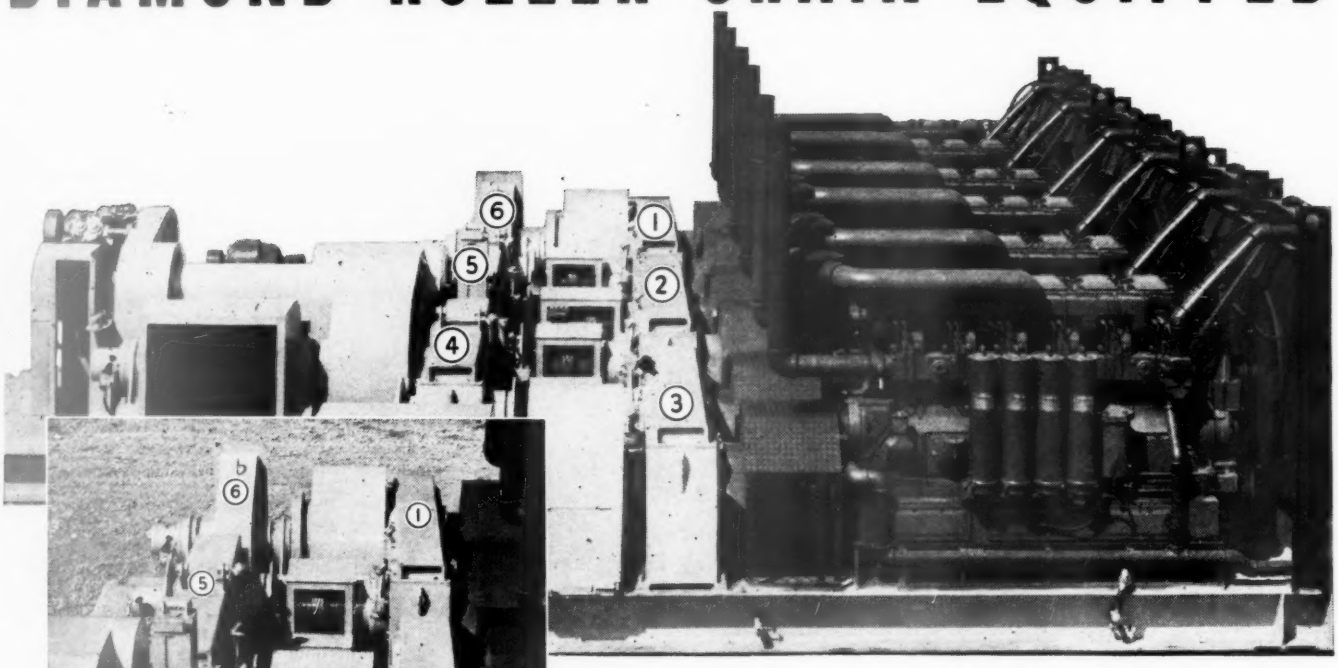

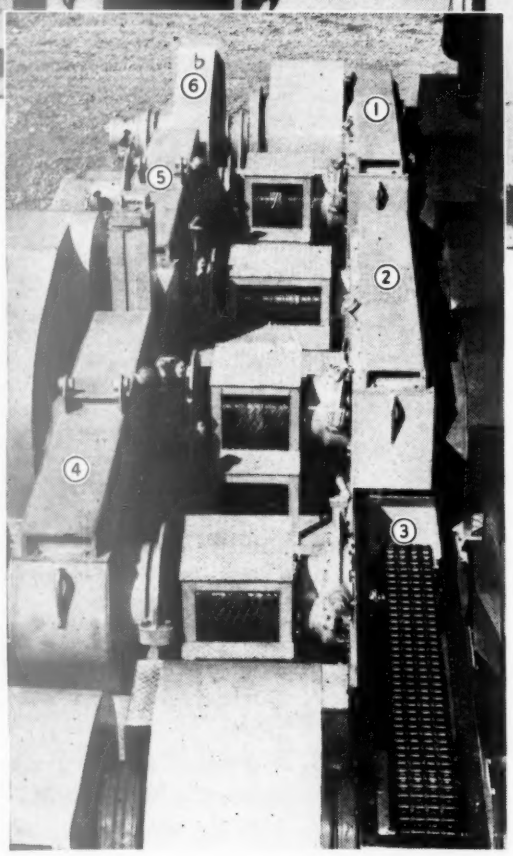

The power of each of three pairs of 240 HP engines is compounded with Diamond Quad. Roller Chains — 1, 2, and 3. Cover has been removed from 3 in the left-hand illustration.

Each of the two main compounds, 4 and 5, is also equipped with a Diamond Quad. Roller Chain. Drawworks drive with Diamond Six Strand Roller Chain is at 6.

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DIAMOND ROLLER CHAINS

DESIGN OF MULTI-COLUMN PLANTS FOR DISTILLATION OF NATURAL GASOLINE

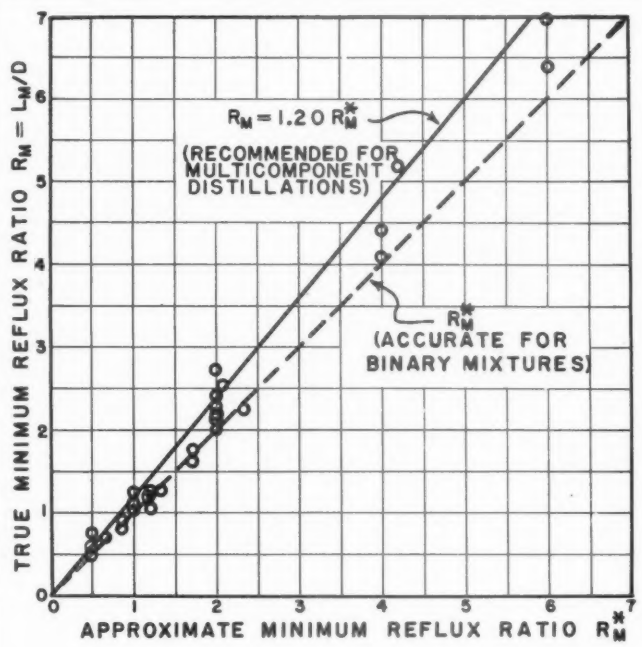
TRUE MINIMUM REFLUX RATIO $R_M = L_M/D$
APPROXIMATE MINIMUM REFLUX RATIO R^*_M
$R_M = 1.20\ R^*_M$
(RECOMMENDED FOR MULTICOMPONENT DISTILLATIONS)
R^*_M
(ACCURATE FOR BINARY MIXTURES)

FIG. 1. Accuracy of minimum reflux calculation recommended for estimating purposes.

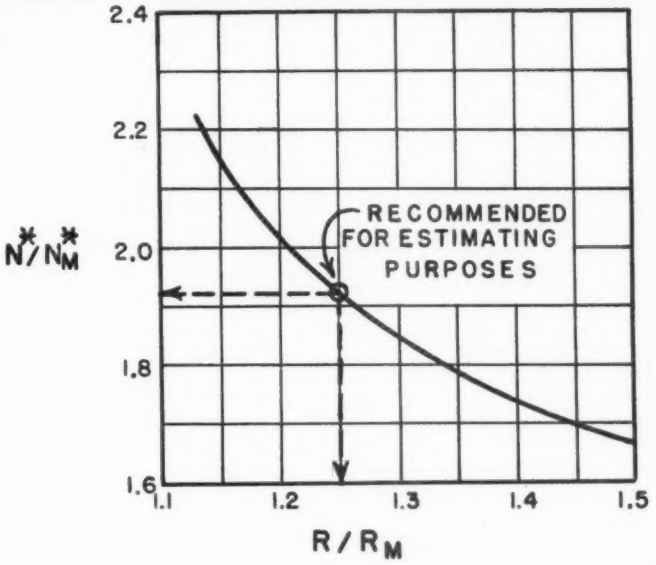

FIG. 2. Relationship between actual reflux ratio and number of theoretical liquid-vapor equilibrium contacts.

THE separation of natural gasoline into its various components by distillation has received much attention with respect to the design of individual columns, but little attention has been given to the possible sequences of distillation columns that may be used to produce three or more products. This paper presents economic comparisons of a number of possible process arrangements of distillation sections in present day natural gasoline plants. Emphasis is placed upon the sequences of deethanizing, depropanizing, deisobutanizing, and debutanizing of natural gasoline.

● **Product quality.** Calculations were made in all cases for the following product specifications: (1) Natural gasoline with 12 lb RVP, containing approximately 1 per cent butanes; (2) n-butane, containing 5 per cent isobutane and 3 per cent pentanes; (3) isobutane, containing 5 per cent n-butane and 3 per cent propane; (4) comercial propane, containing about 2 per cent ethane and 2 per cent butanes; (5) ethane and lighter, containing sufficient propane to obtain condensation for reflux at 450 psig and 100 F.

● **Estimating procedure.** As this paper is concerned only with the comparison of different sequences of columns to obtain the same products, incremental costs are used instead of total costs.

The minimum number of theoretical liquid-vapor contacts is calculated from the Underwood[10] or Fenske[5] equation:

$$N^*_m \log L = \log\left(\frac{x_{LKD}}{x_{hKD}} \times \frac{x_{hKW}}{x_{LKW}}\right) \quad \ldots\ldots\ldots\ldots (1)$$

Where:

N^*_m = minimum number of theoretical liquid-vapor contacts (includes reboiler and partial condenser if present),

L = average relative volatility of the light key component referred to the heavy key component,

x_{LKD}, x_{LKW} = mol fractions of the light key component in the overhead product and bottoms product, respectively,

x_{hKD}, x_{hKW} = mol fractions of the heavy key component in the overhead and bottom products, respectively.

The minimum reflux ratio required for the separation cannot be determined accurately for multicomponent mixtures by any short, simple method. The Underwood equation[10] is accurate for binary mixtures, but is conservative for multicomponent mixtures. Equation (2) applies when the feed is at its bubble point, being identical with the corresponding Underwood equation for binary mixtures.

$$R^*_m = \frac{(x_{LKF} + x_{\bullet KF})}{L - 1} \frac{x_{\bullet LKD}}{x_{LKF}} \left(-\frac{L x_{hKD}}{x_{hKF}}\right) \quad \ldots\ldots (2)$$

Where:

R^*_m = approximate reflux ratio calculated by equation (2) equals L_m^*/D.

x_{LKF}, x_{hKF} = mol fractions of light key and heavy key components, respectivly, in the feed to the column.

All other symbols as defined in equation (1).

The approximate minimum reflux ratio calculated from equation (2) is compared with the true minimum reflux ratio in Fig. 1, the points shown being for multicomponent distillations reported in the literature[2,3,6]. It is recommended that for estimating purposes, the value of the minimum reflux ratio be taken as 1.2 times the value of R^*_m calculated by equation (2) for multicomponent distillations. It should be emphasized that this procedure gives a value of minimum reflux ratio accurate to about 15 per cent only when the feed to the column is at or near its bubble point.

The relationship between the actual reflux ratio and the number of theoretical liquid-vapor contacts required for the separation is given in Fig. 2. This relationship is a simplified form of the Brown and Martin[2] and the Gilliland[7] correlations, and is accurate for most cases encountered in industry (the feed at or near its bubble point, the minimum reflux ratio between 0.5 and 15, and the minimum number of theoretical liquid-vapor contacts between 6 and 50). It is recommended that for design purposes the actual reflux ratio be taken as 1.25 times the minimum reflux ratio, because this point corresponds with the economically optimum operation of most hydrocarbon distillation columns.

Note: References are shown on the last sheet in this series.

Taken from the paper, "Multi-column Distillation of Natural Gasoline," by Frank J. Lockhart that was presented before California Natural Gasoline Association, Los Angeles, and published in *The Petroleum Engineer*, August, 1947, pages 111 to 118, inclusive.

Fifty years of engineering experience and skill are built into this unit, made by Parkersburg Rig and Reel Company. Among its many desirable features are Hyatt Roller Bearings in the Pitman Wrist Pins, contributing to long, dependable trouble-free life.

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HYATT ROLLER BEARINGS

DESIGN OF MULTI-COLUMN PLANTS FOR DISTILLATION OF NATURAL GASOLINE

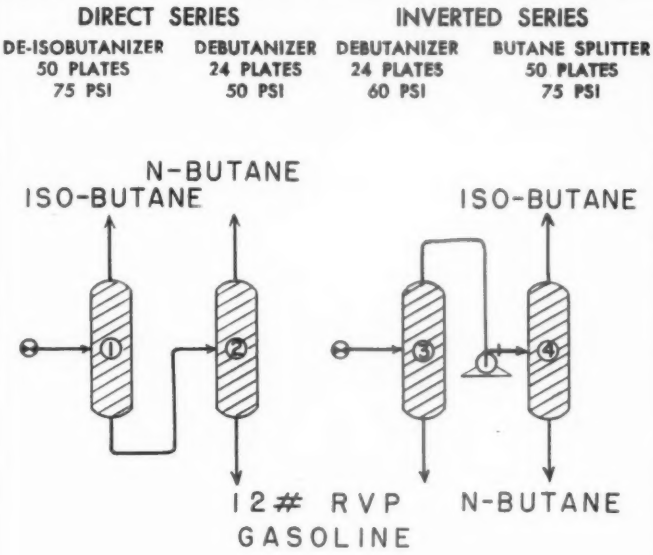

FIG. 3. Sequences of de-isobutanizing and debutanizing natural gasoline.

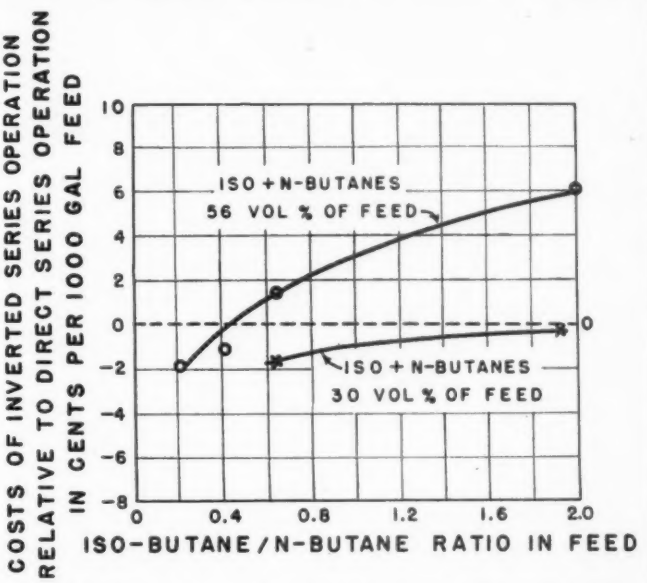
COSTS OF INVERTED SERIES OPERATION RELATIVE TO DIRECT SERIES OPERATION IN CENTS PER 1000 GAL FEED
ISO + N-BUTANES 56 VOL % OF FEED
ISO + N-BUTANES 30 VOL % OF FEED
ISO-BUTANE/N-BUTANE RATIO IN FEED

FIG. 4. Costs of inverted series relative to direct series for production of iso-butane, n-butane, and 12-lb RVP gasoline.

Overall plate efficiencies, used to convert the number of theoretical liquid-vapor contacts to the number of actual bubble cap plates, may be obtained conveniently from the correlation of Drickamer and Bradford[4] or that of O'Connell[5].

Plate spacings of 25 in. were used in all calculations in this paper. Column diameters were estimated by the correlation of Souders and Brown[9] as modified by Brown and Lockhart[1], and rounded to the next larger half-foot.

Design pressures were considered as 50 psi higher than operating pressure. Deethanizers were limited to 450 psig operating pressure in all cases.

● **Sizing of extraneous equipment.** Heat exchanger loads were determined by conventional heat balances. All product and reflux streams were cooled to 100 F, while cooling water in all cases had an allowable temperature rise of 30 F. The reboilers for columns used 150 psi steam, with the control valves in the steam line 70 per cent opened in all cases, except those specifically mentioned later.

The only pumps considered in this study were those required to transfer feeds to columns from lower-pressure accumulators.

● **Cost analyses.** Fixed charges (depreciation, maintenance, etc.) were taken as 20 per cent per year of the initial investment costs, which include the costs of columns, heat exchangers, and pumps on an incremental basis. The cost of columns, erected in the Los Angeles area and complete with insulation, ladders, and platforms, was taken as 20 cents per lb total weight, a figure in agreement with turnkey estimates made in 1946. The costs of heat exchangers varied from $4 to $8 per sq ft transfer area, installed basis, in accordance with 1946 quotations. The cost of pumps and drivers were also in accordance with 1946 estimates, installed with connecting piping.

Operating charges were based on the following unit cost figures:

150 psi steam	20 cents per M lb
Cooling water	0.5 cent per M gal
Power	0.5 cent per kwhr
Fuel	15 cents per MM Btu

TABLE 1. Feed stocks corresponding with Figs. 3 and 4.

	Feed A	Feed B
Rate, gal per hr	2200.0	4100.0
Composition, vol per cent:		
Propane	0.4	0.2
Isobutane	56.5	30.3
n-Butane		
Isopentane	16.9	27.2
n-Pentane	8.8	14.2
Heavier	17.4	28.1
	100.0	100.0

● **Scope of the calculations.** Production of the five streams specified previously requires four distillation columns in most instances. It is possible to arrange these four columns in at least 14 different sequences. An attempt has been made to simplify the comparisons of different sequences by considering a number of separations requiring two columns for three products. Specifically, the following cases were investigated: (a) Separation of depropanized gasoline into isobutane, n-butane, and 12-lb. RVP gasoline; (b) separation of deethanized gasoline into propane, isobutane, and deisobutanized gasoline; (c) separation of raw natural gasoline into ethane and lighter, propane, and depropanized gasoline. Results of the study are presented in that order.

● **Deisobutanizing and debutanizing gasoline.** After propane and lighter constitutents have been removed, two distillation columns are required to produce isobutane, n-butane, and 12-lb RVP gasoline. The columns may be placed in either the so-called "direct" series or the "inverted" series as indicated in Fig. 3. These two sequences have been compared for the feed compositions and rates indicated in Table 1.

The feed rates listed in Table 1 were selected so that all column diameters would be at least 2 ft. Feed B is a heavier stock than Feed A; it also represents the total feed where Feed A is the net feed and two volumes of gasoline are recycled to the still per volume of net gasoline product.

Results of this study are shown in Fig. 4. It is to be noted that the costs given in Fig. 4 represent the differences between the costs of operation of the inverted series and the direct series for the same feed and products. The ratio of isobutane to n-butane in the feed is ordinarily between 0.2 and 0.7 for natural gasoline stocks but the curves were extended to a ratio of 2/1 to include many refinery operations.

Note: References are shown on the last sheet in this series.

Taken from the paper, "Multi-column Distillation of Natural Gasoline," by Frank J. Lockhart that was presented before California Natural Gasoline Association, Los Angeles, and published in *The Petroleum Engineer*, August, 1947, pages 111 to 118, inclusive.

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DESIGN OF MULTI-COLUMN PLANTS FOR DISTILLATION OF NATURAL GASOLINE

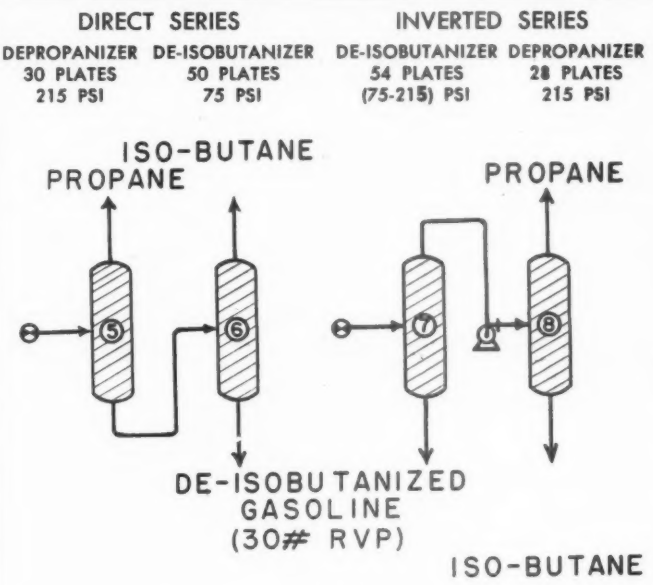

FIG. 5. Sequences of depropanizing and de-isobutanizing operations.

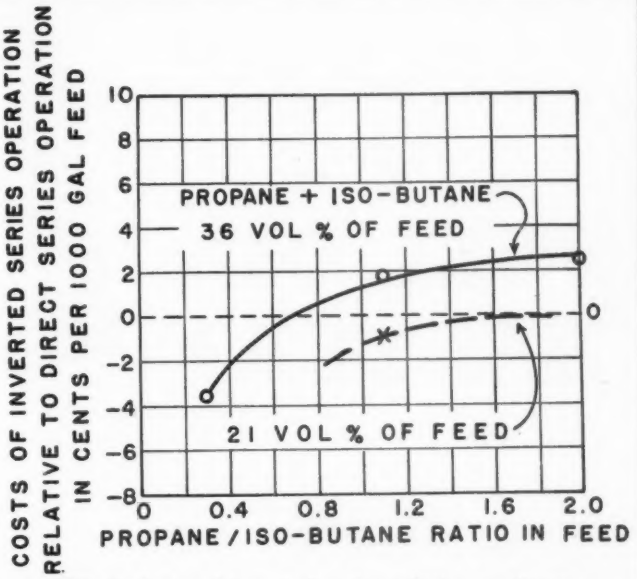
COSTS OF INVERTED SERIES OPERATION RELATIVE TO DIRECT SERIES OPERATION IN CENTS PER 1000 GAL FEED
PROPANE + ISO-BUTANE 36 VOL % OF FEED
21 VOL % OF FEED
PROPANE/ISO-BUTANE RATIO IN FEED

FIG. 6. Costs of inverted series relative to direct series for production of propane, iso-butane, and de-isobutanized gasoline (RVP-30 lb.).

The inverted series compared with the direct series has in general higher fixed charges, principally due to the feed pumps required for the second column, and a lower operating cost, principally due to the reduction in steam consumption. It is interesting to note that the reflux rates are about 10 per cent lower for the inverted series operations.

The following conclusions may be applied to new plants and also to existing plants in which the addition of a new column is planned to separate mixed butane into isobutane and n-butane:

(1). If the isobutane concentration in the depropanized gasoline is relatively high, say more than 30 vol. per cent, as in some refinery operations, the direct series is preferred.

(2). If the isobutane concentration in the depropanized gasoline is relatively low, say less than 15 vol. per cent, the inverted series is preferred.

(3). If the gasoline concentration in the depropanized gasoline is relatively high, say more than 70 vol. per cent, the inverted series is preferred.

(4). For cases not covered by the first three conclusions, either series may be used without undue loss. The optimum sequence must be determined for each individual problem, and will depend upon such factors as the specific feed rate, the sizing of equipment, and the unit cost figures.

● **Depropanizing and deisobutanizing operations.** The separation of the deethanized feed into propane, isobutane, and deisobutanized gasoline may be accomplished by either a direct series or inverted series as shown in Fig. 5. These two sequences have been compared for the feed compositions and rates given in Table 2.

The feed rates listed in Table 2 were selected so that all column diameters would be at least 2 ft. Feed C and Feed D of Table 2 correspond to Feeds A and B of Table 1. Feed D represents the total feed to the depropanizer where Feed C is the net feed and two volumes of 12-lb RVP gasoline are recycled to the still per volume of net gasoline product.

Fig. 6 shows the results of this comparison and is similar to Fig. 4. The ratio of propane to isobutane in the feed is ordinarily greater than 1.0 for natural gasolines, but the curves were extended to a ratio of 0.3/1 to include many refinery operations. The inverted series compared with the direct series has in general higher fixed charges and lower operating costs. Reflux rates for the inverted series are about 5 per cent lower than those for the direct series. The higher pressure-level of the inverted series in Figs. 5 and 6 apparently has little significance in the pressure range of 50 to 215 psi.

The following conclusions are obtained from Fig. 6:

(1). If the propane concentration in the deethanized feed is relatively high, say more than 20 per cent, the direct series is recommended.

(2). If the propane concentration in the deethanized feed is relatively low, say less than 10 per cent, the inverted series is recommended.

(3). If the deisobutanized gasoline amounts to more than 80 per cent of the deethanized feed, the inverted series is recommended.

(4). For cases not covered by the above recommendations, either series may be used with very little difference in cost.

● **Deethanizing and depropanizing operations.** The removal of ethane-and-lighter fractions and propane from natural gasoline may also be compared with respect to the direct series and the inverted series operations, analogous to the sequences shown in Figs. 3 and 5. The significant difference is the large change in the pressure level of direct series and inverted series of this case.

TABLE 2. Feed stocks corresponding with Figs. 5 and 6.

	Feed C	Feed D
Rate, gal per hr	2570.0	4500.0
Composition, vol per cent:		
Ethane	0.4	0.2
Propane	36.3	21.5
Isobutane		
n-Butane	28.0	16 9
Isopentane	13.8	23.3
n-Pentane	7.2	12.8
Heavier	14.3	25.3
	100.0	100.0

TABLE 3. Ethane/propane ratio in feed greater than 0.6.

	Direct series	Inverted series
Operating pressure, psi	(1) 450, (2) 215	(1) 450, (2) 450
Compressors	none	one
Heat supply required for reboilers	(1) 150 psi steam (2) 150 psi steam	(1) 400 psi steam or fired reboiler (2) 150 psi steam

Note: References are shown on the last sheet in this series.

Taken from the paper, "Multi-column Distillation of Natural Gasoline," by Frank J. Lockhart that was presented before California Natural Gasoline Association, Los Angeles, and published in *The Petroleum Engineer*, August, 1947, pages 111 to 118, inclusive.

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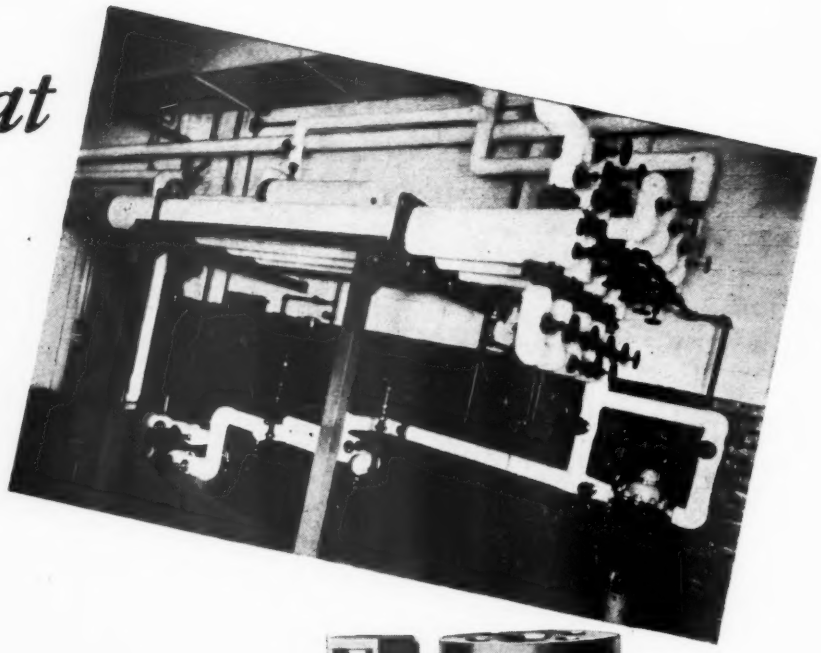

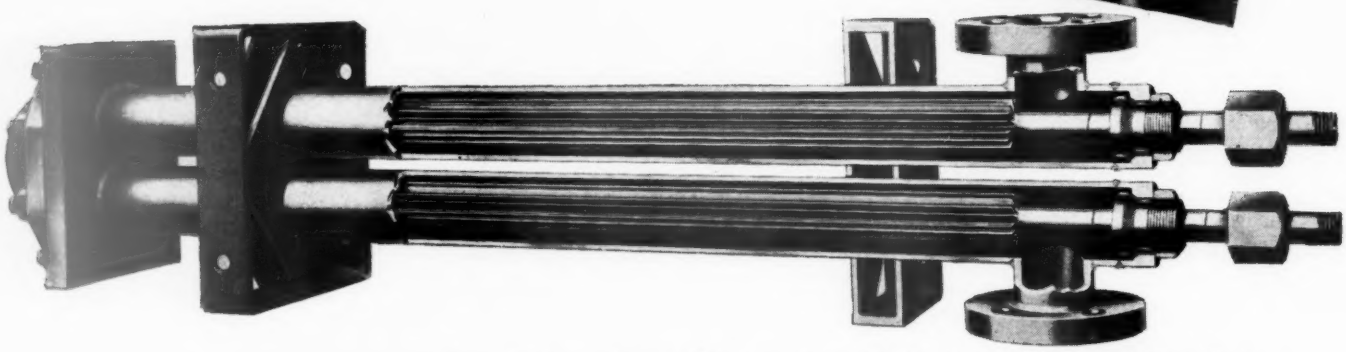

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COMPACT — The longitudinal G-Fins provide at least six times as much heat transfer surface as bare tubes . . . the result: the Twin G-Fin unit has fewer tubes than any other type of heater.

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GRAPHICAL SOLUTION FOR ECONOMICAL ALIGNMENT OF PIPE LINES

If three pipe lines differ in size and unit cost, the shortest route will not be the cheapest. The most economical route can be located graphically by drawing a triangle similar to a force diagram (Fig. 1) using the unit cost of the three legs of the pipe line as the length of the three sides of the triangle. With this triangle drawn on tracing paper two sides can be extended to a sufficient length and a parallel to the third side drawn through the intersection of the other two sides giving three lines that extend radially from a common point.

By placing this tracing over the map so that the three lines pass through their respective end points on the map, a pin prick or pencil dot on the map at the point of intersection of the three lines on the tracing will locate the intermediate point for the most economical route.

In instances where the line route of one leg is fixed by terrain, highway, right-of-way, or some other limiting conditions, the shortest and/or most economical point from which to branch to the other two points is determined in the same manner except that the pin hole or point of intersection of the three lines on the instrument is positioned directly over the fixed leg so that two lines pass through their respective points. There are limitations to this application and it is well to check the perpendicular in instances where one branch intersects the fixed route with an included angle of 90 deg or less.

Figs. 2 and 3 illustrate that the graphic method is accurate and quick.

The shortest distance connecting four points can be plotted in much the same manner using two of the celluloid instruments, one for two points and one for the other two, and positioning them so that two legs of each instrument pass through its two points on the map while the third leg passes through the pin hole of the other instrument. This will give two intermediate points on the map, which when connected together and each to its respective end points will give the shortest connecting distance. These routes cannot always be followed exactly, but are useful as guides.

FIG. 1

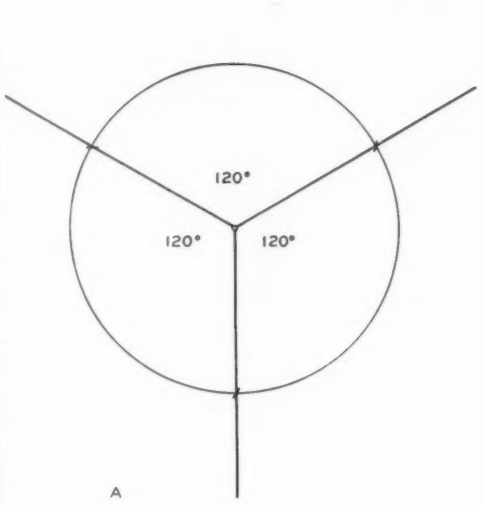


Diagram for locating the shortest distance connecting three points.

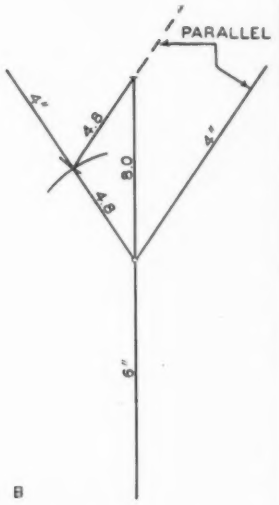
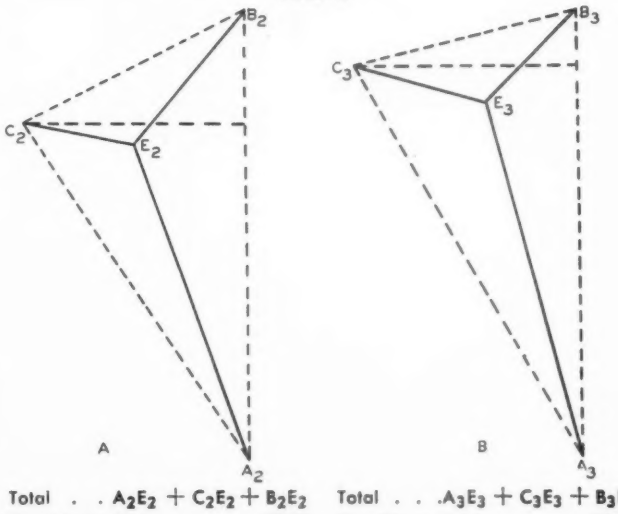


Diagram for locating the most economical route of a pipe line connecting three points when two of the branches are to be 4 in. costing $4,800 per mile and one branch 6 in. at $8,000 per mile.

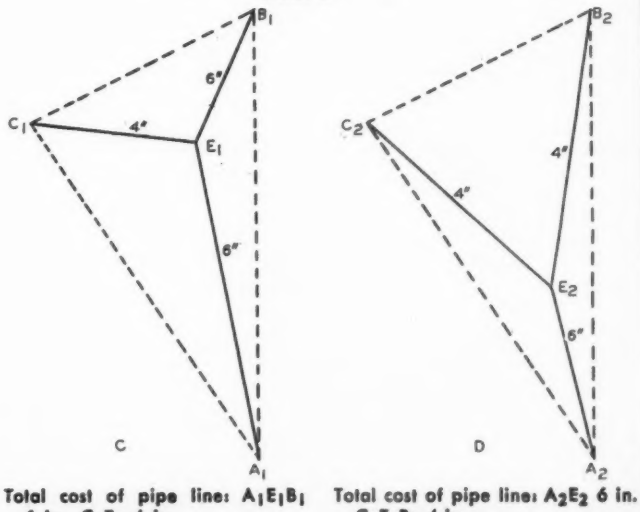
FIG. 2



	$A_2E_2 + C_2E_2 + B_2E_2$		$A_3E_3 + C_3E_3 + B_3E_3$
Total		Total	
Graphic method	27.75	Graphic method	28.32
Bryan method	27.88	Bryan method	28.65

Scale 1" = 8 units

FIG. 3



Total cost of pipe line: $A_1E_1B_1$ 6 in., C_1E_1 4 in.
Graphic method: 7.41 miles 4 in. at $4,800 per mile = $35,568. 20.83 miles of 6 in. at $8,000 per mile = $166,640. Total cost of pipe line = $202,208.
Bryan method: $202,528.
Scale 1" = 8 miles

Total cost of pipe line: A_2E_2 6 in. $C_2E_2B_2$ 4 in.
Graphic method: 23.50 miles 4 in. at $4,800 per mile = $112,800. 7.90 miles of 6 in. at $8,000 per mile = $63,200. Total cost of pipe line = $176,000.
Bryan method: $183,600.

The Bryan method is described on sheets 1 & 2 of P 615.2, published in the continuous tables in Nov. & Dec., 1947.

Taken from the article "Economical Alignments for Pipe Lines," by Albert J. Geiger published in *The Petroleum Engineer*, August, 1947, pages 161 and 162, inclusive.

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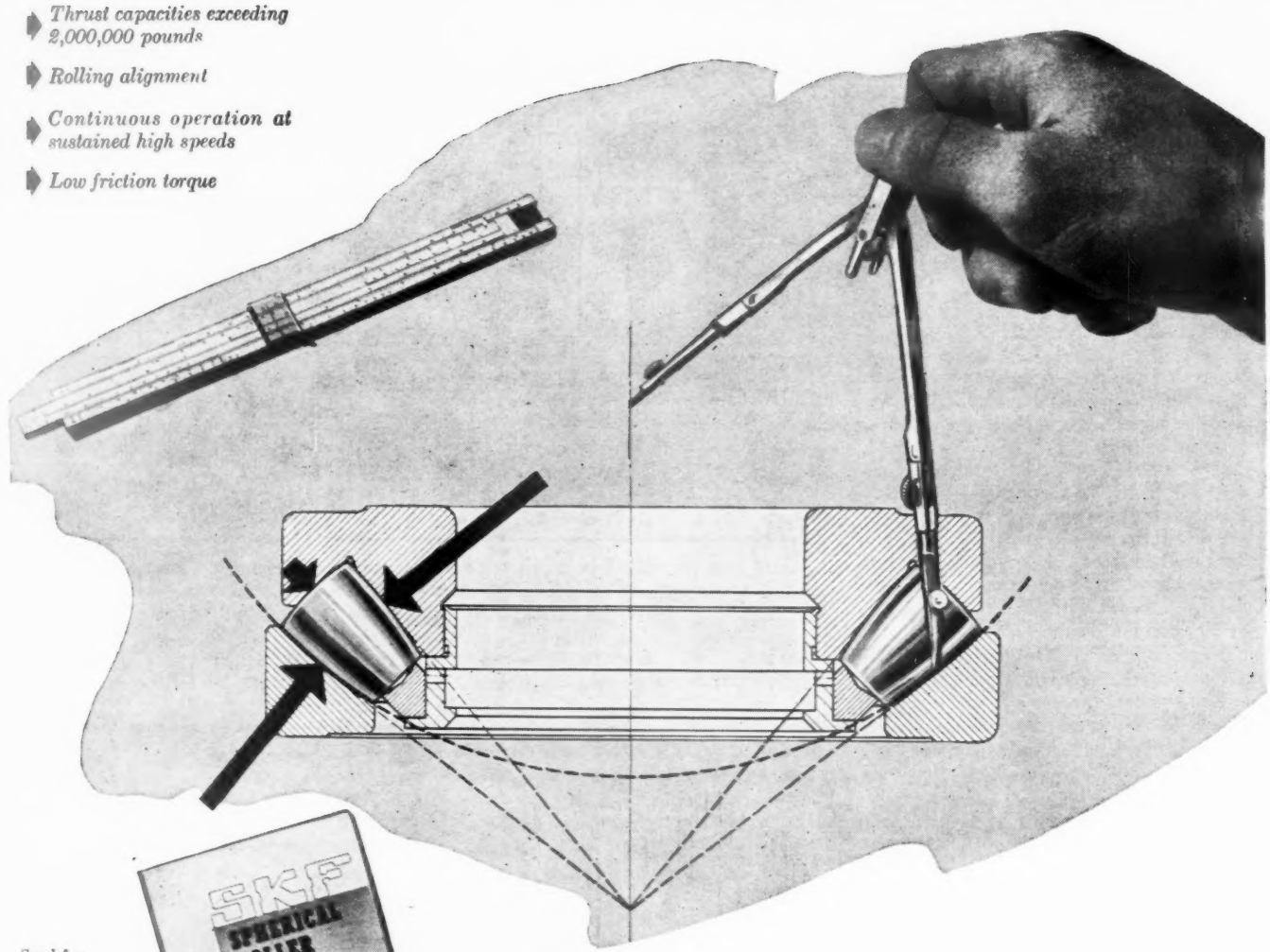
- *Continuous operation at sustained high speeds*
- *Low friction torque*



Send for CAT. 279

The SKF Spherical Roller Thrust Bearing is designed to carry heavy thrust loads at sustained high speeds. This high capacity is not reduced by misalignment between shaft and bearing bore, since the outer race of the bearing is a section of a sphere on which the inner race and spherical roller assembly align freely.

The rollers are so shaped that load components firmly contact the roller ends against the unusually high guide flange. This assures positive guiding of the rollers without excessive pressure on the roller ends.

The bearing is so constructed that oil is pumped outwardly between the rollers, bathing all parts of the bearing in lubricant. 6454

SKF INDUSTRIES, INC., PHILA. 32, PA.

A.I.M.E. section officers

Newly elected officers of the North Texas Section of AIME for 1948 are shown in the above photograph. They are: Left to right, Warren J. Jackson, Lane-Wells Company, Dallas, chairman; Dr. Dayton H. Clewell, Magnolia Petroleum Company, Dallas, vice chairman for Dallas; R. E. Heithecker, Seaboard Oil Company, Dallas, secretary-treasurer; Ernest E. Merkt, Gulf Oil Company, Fort Worth, vice chairman for Fort Worth; Dr. E. R. Brownescombe, Atlantic Refining Company, Dallas, director; Tom E. Morton, Halliburton Oil Well Cementing Company, Wichita Falls, vice chairman for Wichita Falls; Charles B. Carpenter, USBM, Dallas, director; Don L. Harlan, The Texas Company, Fort Worth, director, and E. B. Nicholson, Continental Oil Company, Wichita Falls, director. Ben M. Kingston, Chemical Process Company, Breckenridge (not shown above) was elected a director for 1948. Gordon Fisher, Gulf Oil Company, Fort Worth, (not shown) the retiring chairman for 1947, becomes a director for 1948.

Rejoins firm

A. B. (Dick) Grant has rejoined Stewart and Stevenson Services, Inc., as representative for their Laredo district, it is announced by Joe Manning, manager. Grant, a veteran of four years in the army as transport officer in the India-Burma theatre, has been associated with diesel and gas engines for more than 14 years. He spent several years in the Orient before the war as export representative for various manufacturers.

A. B. Grant

As Laredo representative for Stewart and Stevenson, he will have charge of sales and service on GM diesel engines and Continental Red Seal gas engines for the northern section of Mexico and the Wintergarden section of the Rio Grande Valley of Texas.

HARRISBURG
Drop-Forged
Steel

PIPE FLANGES

WE MAKE OUR OWN STEEL

In Harrisburg Drop-Forged Flanges, strength and endurance go hand in hand with accuracy of machining. Forged from Harrisburg's own steel which assures prompt shipment. Threads are perfect in height, angle, taper and gauging. Furnished in all sizes and types.

SEND FOR
THIS COMPLETE CATALOG

•

Sales Representatives

HENRY H. PARIS
Houston, Texas

W. C. NORRIS MFG. CO.
Tulsa, Oklahoma

HARRISBURG STEEL CORPORATION
HARRISBURG, PENNSYLVANIA

Bethlehem promotes

Bethlehem Supply Company announces the transfer of T. H. Gibbs to special representative in its Houston, Texas, sales office. "Ty" Gibbs was formerly field engineer with the Bethlehem Steel Company. He will concentrate his efforts on machinery sales in the Houston area.

I. N. Hall, formerly assistant store manager at Alice, Texas, has been transferred and promoted to store manager and field representative at the Corpus Christi, Texas, store.

R. P. Carpenter, formerly field representative at McAllen, Texas, has been transferred to Alice in the same capacity.

S. I. Snyder has been promoted to field representative at the Harvey, Louisiana, store.

New employes who have recently joined the Bethlehem Supply Company are J. W. Jillson, special representative; Joe Chastain, engineering representative, and W. M. Bartlett, field representative, all of whom are at Odessa, Texas; Melvin Bates, field representative at the Craig, Colorado, store; and R. M. Berman, special representative in the refinery sales department in Tulsa, Oklahoma. R. M. Berman, a graduate of the University of Texas in chemical engineering, was formerly employed by Hercules Powder Company at Wilmington, Delaware, for seven years prior to his becoming affiliated with Bethlehem Supply Company.

HILL, HUBBELL PIPE PROTECTION ...in all Standard Sizes..
EXCLUSIVELY DESIGNED MACHINERY—Embodying many new mechanical features, make it possible for us to coat and wrap your pipe with the highest efficiency—in ALL standard pipe sizes.
PIPE STORAGE SPACE AVAILABLE TO YOU—We take delivery of your pipe when it is released from the mill.
Pipe Sizes from 3/4" nominal to 24" O.D.
HILL-HUBBELL
STEEL PIPE Life
Hill, Hubbell and Company
Division of GENERAL PAINT CORPORATION
3091 MAYFIELD RD. CLEVELAND, OHIO.

Keating to Houston

L. M. Keating, assistant to the president in charge of distribution of the A. O. Smith Corporation, has been appointed executive administrator of the company's Southwest district office in Houston, Texas, it is announced by W. C. Heath, president. Keating replaces B. F. Bart, recently deceased.

L. M. Keating

In making the announcement Heath said, "The nine great states in our Southwest District account for almost 25 per cent of the company's total business. The present growth and development of the area is so rapid that our interests there must be put in the hands of the most competent administrator we can spare from our central management."

To South America

Ed T. Landgraff, manager, New York office of Chiksan Export Company, will leave shortly on a four-month trip through South America, according to L. J. Laird, vice president and sales manager, Chiksan Company, Brea, California. Landgraff will cover all the important oil producing centers on his itinerary, renewing acquaintances among oil men in those areas and establishing resident representatives in the various countries for Chiksan swivel joints, Well Equipment Manufacturing Corporation products, and Okadee valves, which are sold exclusively by Chiksan Export Company.

Ed T. Landgraff

F. E. O'Neill promoted

Frank E. O'Neill has been promoted to the position of assistant to the president of the M. O. Johnston Oil Field Service Corporation.

O'Neill has been active in the oil business in California since 1920. Starting with the oil department of Southern Pacific Railroad he served Pacific Oil Company, Standard Oil Company, and Superior Oil Company. In 1933 he became associated with M. O. Johnston and served this organization as general manager until 1938 when he formed his own oil field research and development business. During the war O'Neill spent 4½ years at USC as a special lecturer on petroleum engineering. Two years ago he rejoined

F. E. O'Neill

the Johnston organization as chief engineer. In his new position as assistant to the president, he will coordinate service operations, manufacturing, sales, engineering, and the business aspect of Johnston's rapidly expanding business.

Personnel changes

The Continental Supply Company, Dallas, Texas, has announced several personnel changes in the company's export division, effective as of March 1.

Julio Zumeta

Julio Zumeta, for the last two years export representative in South America, has been appointed executive manager of exports, with offices in New York. He succeeds F. L. Convers who has retired.

Charles J. DeLay, long identified with the New York office, is now manager of the export division.

C. J. DeLay

W. F. Ellebrecht

W. F. Ellebrecht, for the past few years handling sales promotion work in the Dallas office, has been named Dallas export representative.

To new office

Karl W. Schick, Southwest regional manager, Minneapolis-Honeywell Regulator Company, announces that on April 1 D. J. Fair was transferred from the Dallas office to open a district office for the Brown Instrument Division in Shreveport, Louisiana. Offices are at 330 Garrett Building, 940 Margaret Place, Shreveport. Fair has been assigned to the Dallas office as industrial sales engineer for the last 18 months and in opening the Shreveport office continues to serve the customers in the East Texas, Northern Louisiana, and Southwest Arkansas areas.

D. J. Fair

Additional personnel has been added to the Brown Instruments Division in the Dallas office. Increased activity in all branches of industry within this area are responsible for this move, it is announced.

Charles F. Woods will continue to assist Fair in the territory.

Do you need money?

W-K-M Company, Inc., Houston, Texas, wants to get rid of some money. For several years the company has been holding dividend checks for a few individuals whose present addresses are unknown, says J. D. Rice, secretary and sales manager, and he would appreciate hearing from these persons or anyone who may know their whereabouts. The company address is P. O. Box 2117, Houston, and the names and last known addresses of the missing persons are as follows:

H. Berkefeld, 1503 West 18th Street, Pine Bluff, Arkansas; George Edward Delaney, 429 Omar Street, Houston, Texas; Graydon Esmond, 2631 Fourth Street, Port Arthur, Texas; C. J. Hannan, 1810 Boulder Street, Houston, Texas; Wm. D. Howells, 205 West Poplar Street, West Frankfort, Illinois; W. W. Kendrick, care Morgan, Seagraves & Morgan Company, Refugio, Texas; F. E. King, care Cardinal Oil Company, McCamey, Texas; Clif Moore, P. O. Box 1492, Wichita Falls, Texas; Halcyon Moore, 4115 Gilbert Street, Dallas, Texas; W. C. Robertson, P. O. Box 131, Andrews, Texas; Homer H. Sloan, P. O. Box 4212, Houston 14, Texas; Ben Steincamp, P. O. Box 2009, Wichita Falls, Texas; Billy T. Zeigler, P. O. Box 1016, Ada, Oklahoma, and Katheryne Louis Zeigler, P. O. Box 1016, Ada, Oklahoma.

FOR THE BEST IN CABLE TOOLS

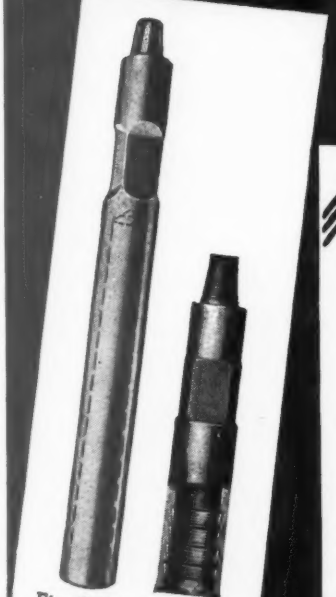


Fig. F476 Fig. F481

For the Close Hole Job
SPANG
SOLID BORED FRICTION SOCKET
(Fig. F 476)
and MULTI-SLIP COLLAR SOCKET
(Fig. F 481)

These tools are intended for fishing where the clearance is close between the fish and the well bore. They frequently save a pin milling job but, obviously, they have limited strength. However, when made to the Spang Higher Standard of tough steel with thorough heat-treatment, they will do more than one might expect.

For the best in Cable Tools, SPECIFY SPANG.

THE HIGHER STANDARD

SPANG & CO.
BUTLER, PA.

YOUR DEALER SELLS SPANG TOOLS

HERE IS THE SOLUTION OF A DIFFICULT *Problem!*

It has always been difficult to perform a successful cement job at some desired point above the bottom of the hole — and at the same time prevent contamination by the cement slurry of permeable, low-pressure zones below the cementing point.

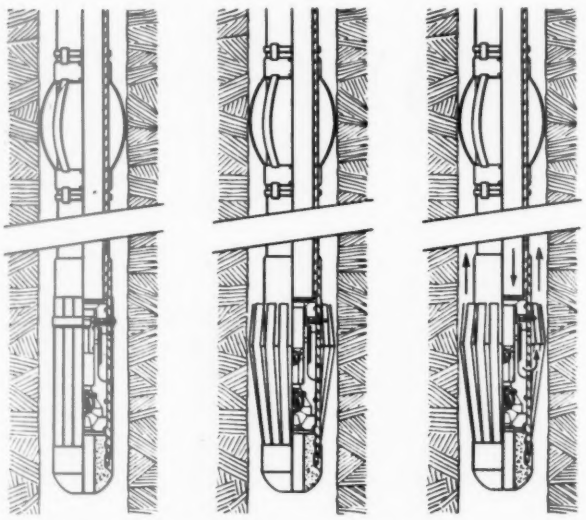
This operation is now safely and efficiently performed by using the Baker Triplex Cementing Shoe (Product No. 136) or the Baker Triplex Cementing Collar (Product No. 138) which is similar in internal construction and in operation to the Triplex Shoe.

The simple operation of TRIPLEX Equipment is evident from the accompanying drawings which illustrate the ease of floating-in casing strings of any size or length — the efficient distribution of the cement slurry — and the protection of permeable, low-pressure zones below.

Get in touch with the Baker representative in your area for prompt, helpful service.

BAKER OIL TOOLS, INC.

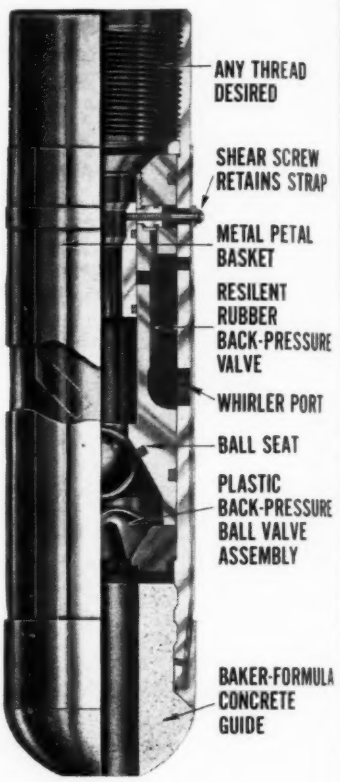
HOUSTON · LOS ANGELES · NEW YORK

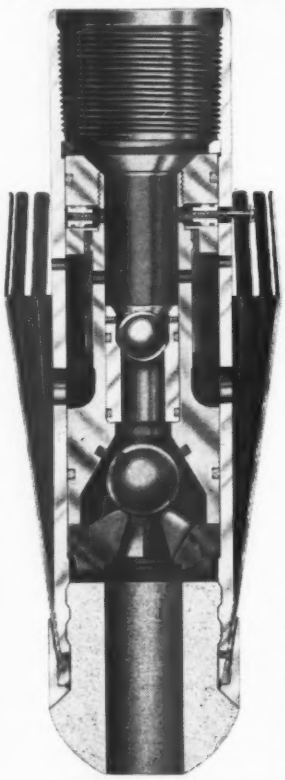


The Baker Triplex Cementing Shoe (left) in running-in position, centered in the hole by a Baker Casing Centralizer. In the center illustration the Tripping Ball has been dropped, seated, and the Tripping Valve forced downward. This action shears the shear screw holding the Metal Petal Basket against the Shoe, and permits the Metal Petal Basket to expand against the side walls of the hole. The ports are now open ready for cementing. At right, cementing is under way, with the slurry directed upward to completely encase the centered pipe with a uniformly thick body of cement with the expanded Basket retaining the cement above the Shoe.

The Baker Triplex Flapper Valve Float Collar (Product No. 134) may be run in place of the Triplex Baffle Collar when an additional float valve is desired. Note how it is designed to permit passage of the Tripping Ball, and how an ample flat surface is provided for "bumping" the cementing plug.

At right the Triplex Shoe is shown in running-in position, with the Metal Petal Basket held against the Shoe by the hold-down strap which is fastened by a shear screw.

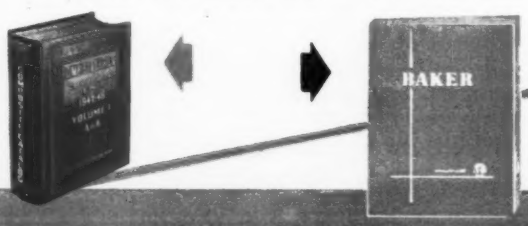




The Triplex Cement Baffle Collar (Product No. 137) is run a joint or two above the Shoe and serves as a stop for the cementing plug, so that mud-contaminated cement is retained inside of the casing. The hole is bevelled at its top to permit easy passage of the Tripping Ball.

(Left) The Tripping Ball has been dropped and seated on top of the Tripping Valve. Pressure of about 500 psi has sheared the shear screws and forced the Tripping Valve down to expose the cementing ports. Shearing the screws also permits the Metal Petal Basket to expand against the side walls and form a bridge which holds the cement slurry **above** the Triplex Shoe and protects permeable, low-pressure zones below from cement contamination.

Complete details are in the 1948 Baker Catalog — and THE COMPOSITE CATALOG



BAKER TRIPLEX CEMENTING EQUIPMENT

Hungry customer (at lunch counter): One roast beef sandwich.

Waiter: Will you eat it here or take it with you?

Customer: I hope to do both.

* * *

Two cockroaches lunched in a dirty sewer, and excitedly discussed the spotless glistening new restaurant in the next block.

"I hear," said one, "that the refrigerators shine like polished silver. The floor sparkles like diamonds. It's so clean."

"Please," said the second cockroach in disgust, "not while I'm eating!"

* * *

Two stuttering blacksmiths had finished heating a piece of pig iron, and one placed it upon the anvil with a pair of tongs.

"H-h-h-h-hit it," he stuttered to his helper.

"Wh-wh-wh-wh-where?" asked the other.

"Ah, h--h-hell, we'll have to h-h-h-heat it again, now."

* * *

"For goodness sake, use both hands!"

"Can't. Gotta drive with one."

* * *

"What foah dat doctah comin' out to yoah house?"

"Ah don' know, but Ah thinks Ah has a little inkling."

* * *

One of those very talkative women buttonholed a fisherman who was minding his own business and said, "Aren't you ashamed of yourself? A great big fellow like you might be better occupied than in cruelly catching this poor little fish."

"Maybe you are right, lady," said the fisherman. "But if this fish had kept his mouth shut, he wouldn't be here."

* * *

The Scotchman awoke one morning to find that his wife had passed away during the night. He leaped from his bed, ran out into the hall, and called downstairs to the cook: "Mary, come to the foot of the stairs quick!" "What is it?" she cried. "Don't boil but one egg for breakfast," said the Scotchman.

* * *

We have it on good authority that the addition of a glass of beer often improves the flavor of a pinch of salt.

* * *

Little Tobey was telling his mother about the day in school. "Mother," he said, "today our teacher asked me whether I had any brothers or sisters, and I told her I was the only child."

"And what did she say?" asked his mother.

"She said, 'Thank goodness'!"

Three managers of chicken farms in Russia were being questioned by an investigator. "What do you feed your chickens?" he asked the first.

"Corn."

"You're under arrest! We use corn to feed people!"

The second overheard this conversation, and tried to play safe.

"What do you feed your chickens?" came the question.

"Corn husks."

"You're under arrest! We use the husks to make cloth. And you?" he asked, turning to the third man.

"I give my chickens the money and tell them to go and buy their own food."

* * *

"What's that mark on your nose?"

"That was made by glasses."

"You ought to tilt your head back—it pours easier."

* * *

"At last," groaned the elderly diner, "total paralysis of the left leg! I've feared it for years."

"If it will relieve your mind any," whispered the sweet and more or less demure young thing on his left, "it's my leg you've been feeling."

* * *

Someone shipped two rabbits to the East by motor transportation. The crate arrived with two rabbits. That's fast transportation!

Susie (just home from a date): Hot dog! That fellow Johnny had everything!

Jane: What do you mean, he had everything?

Susie: He must have had everything; he didn't ask me for anything.

* * *

A Scotchman not feeling so well, called on Doctor Pugh, who looked him over and gave him some pills to be taken at bed time. Whiskey was also prescribed for his stomach, a small glass to be taken after each meal.

Four days later the patient called on the doctor, stating he was feeling no better.

"Have you taken the medicines exactly as I instructed?" the doctor inquired.

"Well, doctor," replied the patient, "I may be a wee bit behind wi' the pills, but I am six weeks ahead wi' the whiskey.

* * *

A cockney phoned to inquire the rate to Ealing, a suburb of London. The man at the other end of the line couldn't catch the name of the station, so in desperation he asked the cockney to spell it. Quickly came the reply: "E—for 'Erbert, A—whot the 'orses heat, L—w'ere yer goes w'en yer dies, I—whot yer sees wiv, N—whot lays a hegg, G—Gawd bless me. Get me?"

* * *

Policeman: Little boy, do both your dogs have licenses?

Boy: Yes, sir. They're just covered with 'em!

* * *

Employer: Myrtle, who told you that you could neglect your office just because I give you a kiss now and then?

Stenographer: My attorney.

NIGHT and DAY
ONAN ELECTRIC PLANTS
SPEED OIL FIELD JOBS
For any kind of lighting, for operating electric tools and equipment, dependable Onan Electric Plants do the job under the severest of oil field conditions. Ruggedly built to run at full capacity continuously with a minimum of upkeep, Onan Plants have earned a reputation for low-cost reliability from coast to coast and around the world.
Lightweight one and two-cylinder air-cooled models for maximum portability. Onan two, four and six-cylinder water-cooled plants for continuous operation. Gasoline-powered from 350 to 35,000 watts. Diesel-powered from 2,500 to 35,000 watts.
D. W. ONAN & SONS INC.
KEY ROYALSTON AVE. • MINNEAPOLIS 5, MINN.
Write for Folder
Model 5GO
5000 watts A. C.
Onan PRODUCTS
ONAN ELECTRIC PLANTS

This is What It Takes to Build
WISCONSIN *Air-Cooled* ENGINES

Trainloads of cast iron, bar steel, sheet steel and drop forgings; thousands of Timken roller bearings, magnetos, carburetors, fuel pumps and many other parts and materials . . . including 20,000 gallons of gasoline per month simply for factory test runs . . . that's what it takes to build Wisconsin Heavy-Duty Air-Cooled Engines!

But above all this *quantity* is the *quality* that is the final product . . . the Heavy-Duty Air-Cooled Wisconsin Engines that are serving Industry so dependably, in so many ways . . . as integral power units on a great variety of equipment, delivering "Most Hp. Hours" of on-the-job power service.

WISCONSIN MOTOR Corporation
MILWAUKEE 14, WISCONSIN
World's Largest Builders of Heavy-Duty Air-Cooled Engines

WRITE TO HARLEY SALES CO.
510 Atlas Building, Tulsa, Oklahoma
M & M Building, Houston, Texas
Oil field distributors for Wisconsin Engines and all types of utility units.

Joins Parkersburg

W. V. Rathbone assumed the position of vice president with The Parkersburg Rig & Reel Company effective April 1. His duties are connected with the manufacturing division of the business. The announcement was made by A. Sidney Knowles, president of the company.

W. V. Rathbone

Rathbone is a native of Parkersburg, West Virginia, and was graduated from Lehigh University with a degree in chemical engineering in 1926. After graduation he was employed by The Parkersburg Rig and Reel Company.

In charge of sales

American Car and Foundry Company announces the appointment of Frederick H. Norton as vice president in charge of sales for the company.

F. H. Norton

Norton joined ACF in April, 1945, as an assistant vice president in the sales department. He succeeds R. A. Williams, who has resigned as a director and vice president in charge of sales to accept the presidency of The Standard Railway Equipment Manufacturing Company.

Sales representative

Cardwell Manufacturing Company of Wichita, Kansas, announces the appointment of Alexander A. Toben as sales representative for Rocky Mountain area to include the states of Colorado, Wyoming, Utah and Montana. Toben is a graduate engineer with considerable practical experience, having for seven years been associated with the Bishop Oil Company of California in that capacity. He is well versed in drilling and production methods, and for the last two years has been engaged in the sale of heavy industrial equipment on the west coast. Toben will make his headquarters in Denver.

A. A. Toben

Ethyl changes

Ethyl Corporation announces the following changes in the management of its gasoline testing laboratories:

The transfer of William C. Ludt, branch manager of gasoline testing in the Tulsa, Oklahoma, laboratory, to branch manager of the laboratory in North Kansas City, Missouri, to succeed Harold L. McIntire, resigned.

The transfer of Charles A. Rankin.

TREAT the WATER

AND YOU HELP THE MUD!

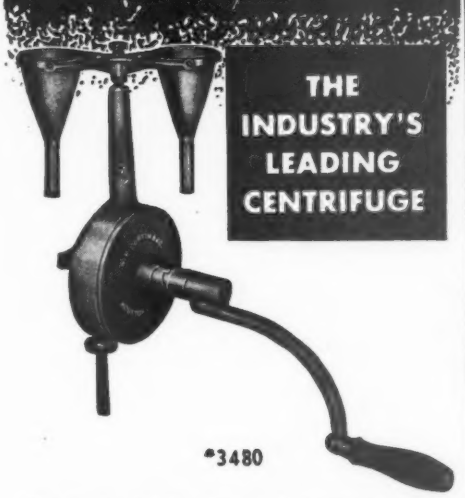
A new approach to help solve mud problems.

• SOLITE is a product specifically formulated to condition water for use in drilling mud.

A laboratory with trained personnel is available to users of SOLITE to assure efficient use of the product.

PAGE TESTING LABORATORY
NORTH VENTURA AVENUE • P. O. BOX 461
VENTURA, CALIFORNIA

HEAVY DUTY-RUGGED....



THE INDUSTRY'S LEADING CENTRIFUGE

*3480

You can maintain your required speed for the full period of the test with much less effort. Curtin centrifuges, proven world-wide, are heavy duty, rigidly constructed, and extremely simple in design. Illustrated bulletin, giving full details, available upon request.

W·H·CURTIN & CO.
HOUSTON .... NEW ORLEANS.

branch manager of gasoline testing in San Bernardino, California, to branch manager at Tulsa, to succeed Ludt.

The promotion of Robert W. Adams, laboratory technician, to branch manager of gasoline testing in San Bernardino, to succeed Rankin.

To new post

John C. Irwin, 36, an attorney for the United States Steel Corporation of Delaware, has been named secretary and general attorney for Oil Well Supply Company, Fred F. Murray, president of this U. S. Steel subsidiary, announces. He succeeds Frank L. Wiegand, Jr., secretary and general attorney since 1945, who resigned to assume a similar position with National Tube Company, another corporation subsidiary.

F. L. Wiegand, Jr.

J. C. Irwin

A graduate of Pennsylvania State College with an A.B. degree in 1934, Irwin received his L.L.B. at the University of Pittsburgh Law School in 1938. He has been a member of U. S. Steel's law department since 1941.

For the present the new "Oilwell" officer will remain in Pittsburgh, but will move to Dallas in the course of the next few months, Murray said.

D+B personnel changes

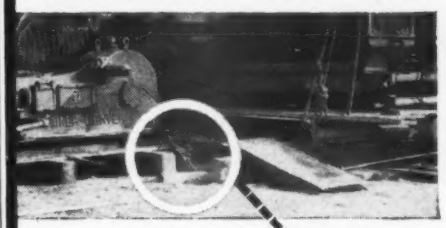
W. C. Kinder, vice president of the Emsco Derrick and Equipment Company and manager of the D+B Division, announces three changes in key personnel. The position of manager of the D+B Mid-Continent Division has been assigned to F. L. Prosser. Herschel Lewis was promoted to Mid-Continent sales manager to fill the position vacated by Prosser, and JoEarl Morris assumed the duties of assistant sales manager previously held by Mr. Lewis.

F. L. Prosser

Herschel Lewis

JoEarl Morris

FOR TOUGH OIL FIELD JOBS
USE A SIMPLEX
EMERGENCY JACK MODEL 310-A

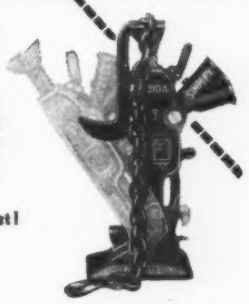


Lifts vertically, lifts or pushes at any angle!

Lifts *full 15 ton capacity* on the machine serrated toe, on the cap, on the auxiliary cap shoe or on any link of 5' chain!

Double lever socket!

14" lift!



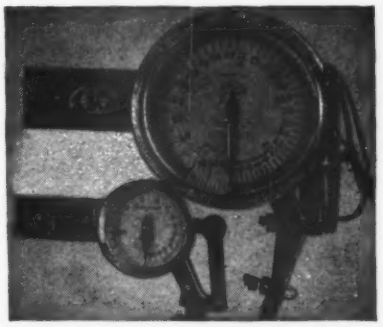
Meets emergency jacking needs in the oil field... with power, safety and easy operation!

SEND FOR BULLETIN: OIL 48

Simplex LEVER • SCREW • HYDRAULIC Jacks

TEMPLETON, KENLY & CO.
1052 S. Central Ave., Chicago 44, Illinois

LINE SCALES

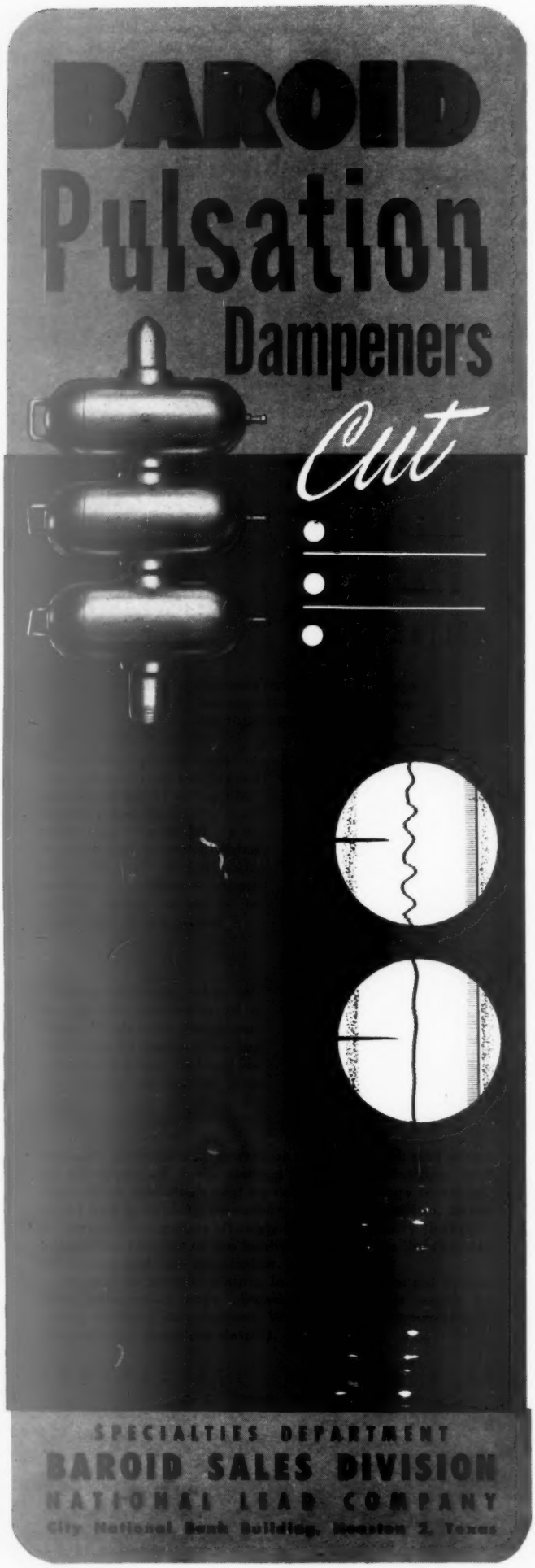


(Above) Super 500,000-lb. capacity, 14" dial. (Below) Packer Special, Capacity 40,000 lbs., 6" dial. 18 other models for every drilling, well servicing, or work-over need.

20 MODELS to choose from

With a LINE SCALE you know the pull on the line, and the weight on the bit in pounds. Repeated tests prove the accuracy and dependability of LINE SCALE readings under all working conditions . . . even in areas of rapid temperature changes.

LINE SCALE CO., Inc.
Box 4245 Oklahoma City Phone 6-1765
Gulf Coast Representative: Hiram Wheeler
Box 8043, Houston 4, Texas—JE-1107



Petrolic Personalities

By DICK SNEDDON

Our competent Mid-Continent scoop sleuth (try saying that after you've had a couple of highballs) was gum-shoeing through a Fort Worth business building recently, doing a bit of keyhole peeking, when suddenly he spotted a rather unusual inscription on one of the doors. *Great Expectations Oil Corporation* it said as plainly as could be, and thinking perhaps the current descendants of Charles Dickens were taking a flutter in the world's most fascinating gamble, he wandered inside with notebook and pencil in hand. You could have knocked him over with a knuckle joint when he discovered presently that the owners of this pretentiously titled enterprise were the well known but distinctly unpretentious Dean family of North Texas and environs. David is president, Paul is secretary-treasurer, and father—W. A. Dean is vice president. The name, Great Expectations, was suggested for the organization by David, because that's exactly what it has, besides, of course, the combined resources and experience of three very successful operators—pioneers in water-flooding, and other consequential departures in drilling and producing technique. Incidentally, Paul recommended a play in Coke County, West Texas, as early as 1921, when he was geologist for the Sun Oil Company. It was right on the beam, too, but the test well wasn't drilled deep enough to strike the Marble Falls producing zone that Sun discovered late last year. He remembers having mapped the surface on two limestone marker beds in the Permian, using a compass and a barometer, but he remembers much better having, on his reconnaissance trip, to open ranch gates by the dozen as his old Dodge touring car transported him in a series of devastating jolts from the County Seat at Robert Lee to the distant town of Silver. He has no personal interest in Coke County now, but when in ruminative mood can occasionally be heard singing, "I dreamt that I dwelt in Marble Falls."

●

Made a call on M. O. Johnston and Bill Bettis down at the new plant on Andrita Street, Los Angeles, the other day, and in the visit found all the savor and surprise of a best selling mystery novel. M. O., Bill, and their several cohorts have erected their own hypothetical iron curtain behind which are going on some mighty intriguing developments, already sufficiently advanced to warrant early disclosure. Hovering around in the background are Johnny Mason, Frank O'Neill, and a number of other engineering wizards, who are so obsessed with the business of creating and perfecting that such insignificant characters as district editors are quite invisible to them. Preparatory to bringing his new contrivances into the open, M. O. has been taking a bit of diversion in the form of a visit to his old stamping grounds in Texas, Louisiana, and other oil areas just beyond the city limits of Los Angeles. We spent a pleasant two hours with him before he left on his barnstorming jaunt, and by a species of mild but insistent probing gathered for the record a lot of hitherto unpublished facts about the Johnston family, their history, and plans. The material has all the drama and pathos of *Gone With The Wind* but is a bit too long for this corner. One thing we might say, however, is that M. O. has always bent an attentive ear to the propounder of a worthwhile idea, and having had a diverse experience both in field operations and manufacturing is a very good judge of what constitutes a worthwhile idea. What he has already done in formation testing and gun perforation is tangible evidence of this capacity. And, familywise, did you know that his two sons M. O. Jr. and Warren have fine singing voices, and are now preparing under excellent tutelage for careers in grand opera or on the concert stage?

●

From widely divergent sources come reports that the 27th annual convention of NGAA at Fort Worth was the biggest thing in an educational way since the invention of the abacus. We are told reliably, we hope, that delegates swarmed in from all parts of the country bearing quartfolios under their arms, and some even came in without swarming, but not, of course,

without quartfolios under their arms. Particularly pleasing to the jugglers of the lower molecular weight hydrocarbons was an "information please" program that was so good they now have one on the radio. Moderator in this free dispensary of air and information was Buck Buchanan, and rumor has it that his performance ought to make Clifton Fadiman blush for shame. Under his subtle direction, a panel of experts answered questions from the floor on every conceivable aspect of gas production, processing, and utilization, and some aspects that were not at all conceivable. The chaff was first removed, however, by a sifting board composed of such dignitaries as Jim Doughty, Southern Mineral Corporation; Pat Bowser, Atlantic Refining Company; V. E. Middlebrook, Shell Oil Company; Frank Stone, La Gloria Corporation, and Carl Wharton, Warren Petroleum Corporation.

Questions relating to general operations were answered by Ray Carter, Stanolind; J. R. Butler, Abercrombie, Inc.; Andy Kirk, California Southern Oil Company, and Merle Church, Shell Oil Company. On LPG and hydrocarbon chemicals, the experts were G. L. Brennan, Warren Petroleum; J. E. Bludworth, consultant. All misunderstanding on engines and pumps was dispelled by J. B. Zachary, Worthington Pump, and Max Landry, Bruce-McBeth Engine Company. W. W. Scheumann of Cities Service dispensed enlightening information on refining. Jim De Flon, Fluor Corporation, and O. L. Smith, Happy Company, handled cooling towers and air cooling with ease. Harold Smith, USBM, was the expert on synthetic hydrocarbons, and R. N. Williams, Elliot Company, simplified the centrifugal blower *ad absurdum* or something. In addition, a battery of fine speakers presented an interestingly diverse choice of topics, and in all respects the convention seemed to satisfy.

Our local operative tells us that California and CNGA were well represented. Red Taylor's enjoyment was somewhat marred by the fact that he kept flipping coins to settle all sorts of important matters, but didn't have any luck. They say some of the coins didn't even come down again. Fred Loomis, the Standard of Cal. gas-expert, found much to remind him of Palo Alto so for him the trip was a nostalgic success. Walt Dayhuff, as usual, knew nearly everybody at the convention and almost wore his arm down to the elbow greeting old acquaintances and making new ones. Andy Kirk added to his reputation as a chef a new reputation as an unusually adept dispenser of affable waters. Clare Gard almost strained his irises looking for some sort of special steaks he had heard about, even after he had had a couple of them. R. D. "Frick" Gibbs was signally honored by being reelected vice president of NGAA. Ed Valby did his usual top job of presenting a paper. Also much in evidence were a threesome from Fluor Corporation—Bob Fluor, Earl Dunn, and Jim Wiseman; and another famous threesome—Ed Ragatz, Harry Marsh and Glen Gill. Then to top off an adventurous session, Ed Millett was wending his way to a technical gathering at the Adolphus when he took the wrong turning and found himself in a miniature icecapade show. He was too much of a gentleman to leave before the show ended, and he was glad he was too much of a gentleman because the show was so good he would likely have stayed anyway. The main event was as usual the Chuck Wagon and Cooling Tower and Jim Richardson, the Bechtel delegate, came so near to missing it that he has been trembling ever since. Concluding this subject, we hear tell that a Life reporter attended the party this year, so the affair is due for a lot of publicity yet.

●

Flittering yon and hither for the next few minutes, Eddie Griswold, the well known Midland petroleum engineer, recently traveled by burro, the old burrocrat, to his gold and silver mine in Mexico. He was accompanied by his son George, who was by no means impressed, and has decided to trek in the opposite direction next time he launches out. George hopes to wind up one of these days in North Alaska, with a post on a seismograph crew for Bart Gillespie or John Legge. From the home of Norris Johnstone, the erstwhile General Petroleum Corp. physicist and production researcher, now a consultant, we received a call a few days ago from our good friend, Nico Van Wingen. Nick was a popular lad out thisaway when he was evaluation engineer for Richfield Oil Corporation in Los Angeles. He is now professor of engineering at the University of Oklahoma, and seems to be enjoying the assignment. We much appreciated the jingle and have made a mental note to do the same thing for him first time we are in Norman, Oklahoma. And

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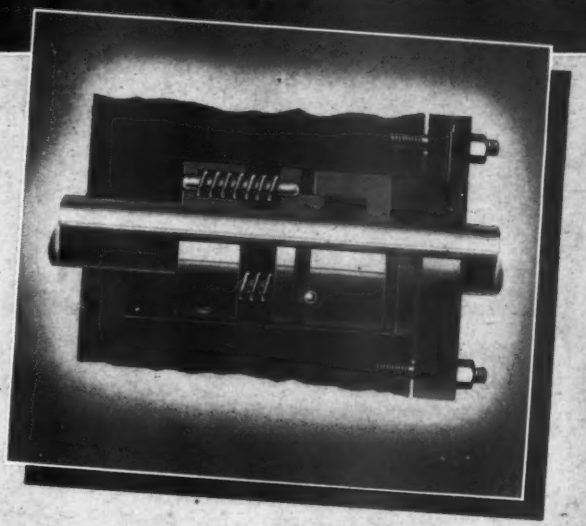

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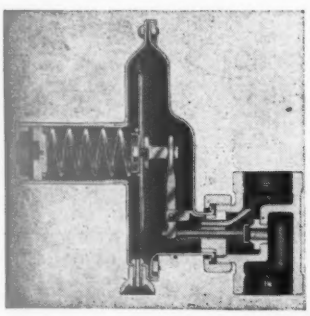

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before we forget, a brief tribute to the late Howard Tinkham whom we have known and admired for many years. Tink, as everyone knew him, was a grand person, and it was a terrific shock to learn of his untimely death. He was unusually well equipped academically to do a fine job for his book and had the right sort of personality to go with it. He was what the trade calls "clean competition," and accordingly in spite of his outstanding success was held in the highest regard by all who knew him. We add our sincere word of sympathy here to the many that must have been extended to his immediate family by the host of his friends.

●

Harold "Forgy" Forgeron, another much respected engineer from the Midland area, returned a short time ago with Mrs. Forgeron from a prolonged vacation in Nassau. They brought back some beautiful kodachrome shots of the island, their beach cavortings, and all the color and romance of a grand time in an ideal spot. When there appeared to be the slightest danger of the landscape becoming monotonous, they simply played golf and changed it, and how they are ever going to settle down to humdrum ordinary existence, they alone know.

Switching back to the Pacific quick like anything we note that the new secretary of the Coast chapter of AAODC is a personable chap, known as William "Frank" Jones, who formerly had his own contracting business here in Los Angeles, and for almost 30 years has been garnering varied experience in all sorts of field operation. For diversion, Frank took to golf some years ago in preference to fishing because in golf you don't have to produce anything to prove your story. Anyway, Frank, congratulations, welcome, and all that sort of nonsense.

●

Incidentally, Ox Morgan and Swede Larson have arranged a new kind of party for the Petroleum Production Pioneers in Brea, California, on April 24, and any old timers from other states who happen to be visiting in California at that time are cordially invited. The affair has been entitled a Broilecue and there is every indication that it is going to bring together a goodly congregation of pioneers. The organization now boasts about 850 members and is still growing like a 1948 schoolboy.

Whence we swing back to Dallas, where Bob Armstrong lately dallied, telling of his water flooding ventures in eastern Kansas. Water was turned into the 400-ft producing section last November—on his properties near Erie—and the production began to increase almost at once. We certainly hope that Bob and his associates will make a lucrative proposition out of this here secondary recovery.

Them Midlanders are sure in the limelight this month. Comes word now that George Kribbs, superintendent of Bankline out yonder, spent a recent weekend with Mrs. Kribbs and several friends in Chihuahua, Mexico, the place that was named after a dog. The report is that a swell time was had and that the party is noticeably refreshed.

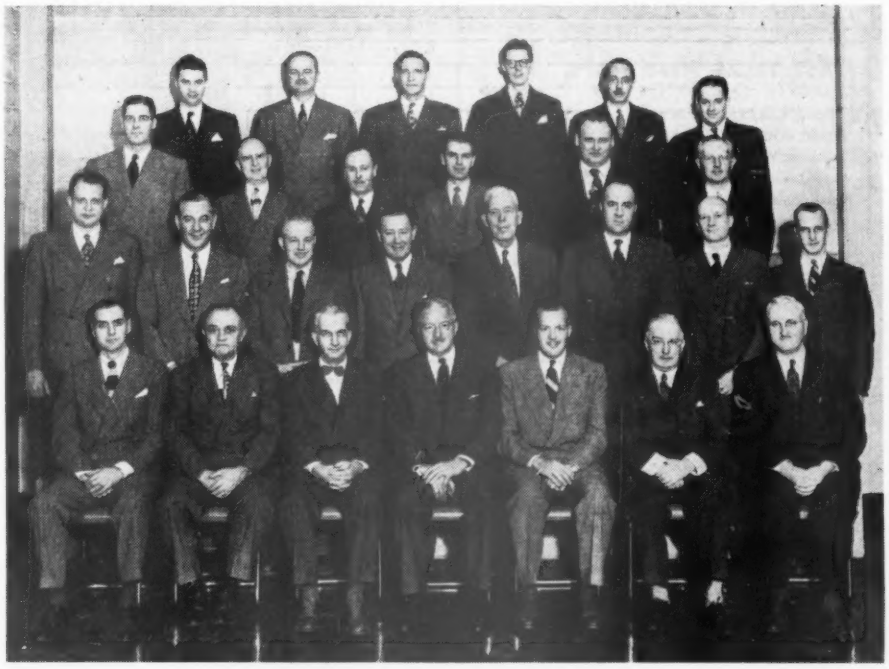
●

Last month we mentioned the fact that Art Flint, a West Coast Shell Oiler, had picked up a cribbage hand that gave him a 29 count—highest possible in the game. Shortly after the release of this bit of news we had a letter from a group of Shell Company delegates down at Drew Station, Lake Charles, Louisiana, asking for an explanation. The group chose as their spokesman, H. C. Lay, and to him we must admit that the statement wasn't too clear. Actually what happened was that the lucky player held in his hand three fives and the jack of the same suit as the fourth five which was the cut. Thus, he held, in effect, four fives and a jack. The count was 16 for fifteens, 12 for the four fives, and 1 for his Nobs, a total of 29, the highest hand available. To H. C. Lay and, indeed, to all our readers, if there are any more, we apologized for allowing mathematics to creep into this column. We have tried very hard to keep it from becoming educational, but occasionally we get hold of an item that we can't resist. Like, for example, just as we go to press comes an exciting invitation from Reese Taylor to attend a preview of the televising of Union Oil Company's 1947 Annual Report. Have no idea yet whether or not it will be some species of animation with graphs drawing themselves as we watch, or a series of departmental reports by the actual executives in charge. But we imagine this is the first time anything of the sort has ever been attempted, and we look forward eagerly to bringing the lowdown in the next issue. Watch this space for further details!

Rockwell division managers hold meeting

Plant managers from the 16 divisions and subsidiaries of Rockwell Manufacturing Company recently held their winter meeting at the home offices in Pittsburgh. Unique among American business meetings, the gathering of Rockwell factory heads permits interchange of operating experiences in production, engineering, research, accounting, sales, advertising, and labor relations at an executive level on a confidential basis and with an unusual lack of restraint since all matters discussed are within the company.

The meetings were instituted several years ago by W. F. Rockwell, Jr., company president, as a means of further coordinating manufacturing activities.



First row, left to right: W. S. Potter, W. H. Newbaker, A. J. Kerr, W. F. Rockwell, Sr., W. F. Rockwell, Jr., E. M. Meyers, C. A. Wilson. Second row: H. C. Stuckeman, J. E. Ashman, H. S. Rockwell, A. E. McIntyre, B. C. Trueblood, W. R. Brown, A. R. Whittaker, C. H. Daugherty. Third row: R. G. Cacuette, N. J. Kenny, A. E. Higgins, L. W. Heavener, R. C. DuBrucq, E. F. Foubert. Fourth row: H. C. Greene, W. F. Crawford, Floyd Snodgrass, Wm. A. Marsteller, C. S. Bygate, L. A. Dixon, Jr.

W. G. Moser advanced

Appointment of William G. Moser as sales manager, Chicago division, Smith Meter Company, has been announced by Harry G. Smith, vice president. With Smith Meter Company since 1938, Moser started in the sales-service department in Chicago. He has had several advancements with the company. His most recent position was assistant sales manager, New York division.

W. G. Moser

Named distributor

Appointment of the Penn Central Equipment Company of Altoona, Pennsylvania, as a distributor of the entire Hewitt Rubber Division's line of industrial hose, conveyor and transmission belting, and packing, is announced by J. H. Hayden, vice president in charge of sales, Hewitt-Robins, Inc., Buffalo.

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Light and compact enough to go in the tool bag, strong enough and with capacity range to hold anything fom small tubing to really large pipe and fittings, these vises are ideal for shop or on-the-job use. All large parts are drop forged steel, small parts are hardened, chains proof-tested. The smaller vises have patented, 1-piece (bridged) jaws that permit a secure hold without danger of kinking even smallest pipe.

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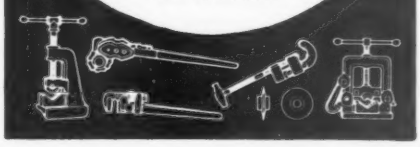

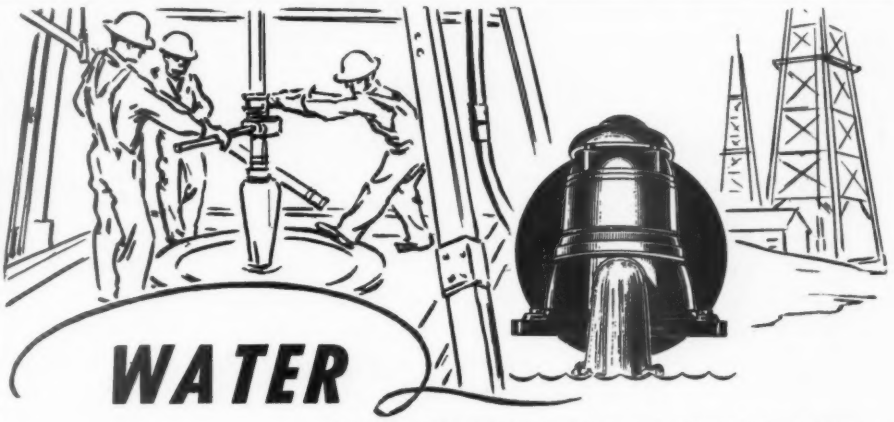

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During the next several months we will increase our Engineering Organization engaged in the design of Oil Refinery Plants and Power Plants. Location Cleveland, Ohio. The men we need should be qualified as draftsmen, designers, checkers or in higher engineering skills on design of piping, instrumentation, pressure vessels, structural steel, concrete, mechanical or electrical. For presenting your qualifications and prompt consideration, write to us for application form.

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Collick promoted

Raymond K. Collick has been named parts merchandising manager of the Detroit Diesel Engine Division, General Motors Corporation, it is announced by V. C. Genn, General Sales Manager. Collick joined Detroit Diesel from Chevrolet as an engineering draftsman in 1937. During the war he served as a technical analyst in connection with the division's extensive parts distribution program for the Navy. With the return to commercial business in 1945, Collick became assistant parts merchandising manager and held that position until his present promotion.

R. K. Collick

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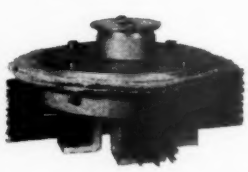

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Hanlon award to G. A. Burrell

The Hanlon Award, highest honor in the natural gasoline industry and one of the ranking awards of the entire petroleum industry, was conferred on Colonel George A. Burrell, president, Atlantic States Gas Company, Inc., New York. The ceremony took place at the 27th annual convention of the Natural Gasoline Association of America being held in Ft. Worth, Texas.

G. A. Burrell

Colonel Burrell is the 12th recipient of the Hanlon Award which is conferred each year by the NGAA for outstanding service to the natural gasoline and cycling industries. Donor of the award is E. I. Hanlon, president fo the Hanlon Companies and chairman of the board of the National Bank of Tulsa, Tulsa, Oklahoma.

Presentation was made by NGAA President C. R. Williams, The Chicago Corporation, Corpus Christi. The citation read in part: "There is little doubt that this man was the first experimenter to make an exact analysis of natural gas. He conceived the type and character of equipment required, made and assembled it himself, and made it work. This was in 1915. It is scarcely open to question that this was one of the most important detail steps in the technological progress of the petroleum-gas field."

Dick White elevated by Franks Corp.

R. M. "Dick" White has been elected vice president and appointed sales director of Franks Manufacturing Corporation of Tulsa as of April 15. White, who has been Franks district manager at Fort Worth, has been with Franks since 1934, except for brief periods with the Noble Drilling Company and with the Oklahoma Iron Works.

R. M. White

White has spent most of his time with Franks in the sales department. He established the Fort Worth office and for years covered Texas, New Mexico, Louisiana, Mississippi, and Arkansas.

Change in managers

Three changes in Oil Well Supply Company store managers are announced by V. J. Waters, Central Midwest division manager for this United States Steel Corporation subsidiary.

Elmer E. Rust, warehouseman in the Anson, Texas, store since joining "Oilwell" in August, 1945, has been named manager. He succeeds Ralph Crowe, who has been transferred as manager of the Greggton, Texas, store. J. N. Tate has been appointed manager of the company's Pampa, Texas, store.

Assistant sales managers

The ball and roller bearing division of Link-Belt Company announces the appointment of Arthur E. Maha as assistant sales manager for the central division, with headquarters at the Dodge plant, Indianapolis, where the company's ball and roller bearings are made.

Announcement is also made of the appointment of Lewis M. Watkin, Jr., as assistant sales manager for ball and roller bearings in the eastern division, with headquarters in Philadelphia.

Both men will report directly to George H. Woody, sales manager, ball and roller bearing division, Dodge plant, Indianapolis.

Supervises mud school

Ed Steele, mud engineer for Oil Base, Inc., makers of Black Magic oil base drilling fluid, has been appointed to supervise the mud school to be held in Bakersfield, California.

Held under the auspices of the American Association of Oilwell Drilling Contractors, classes began in March at Long Beach. Tentative plans call for similar schools in Bakersfield, Whittier, Ventura, and Coalinga.

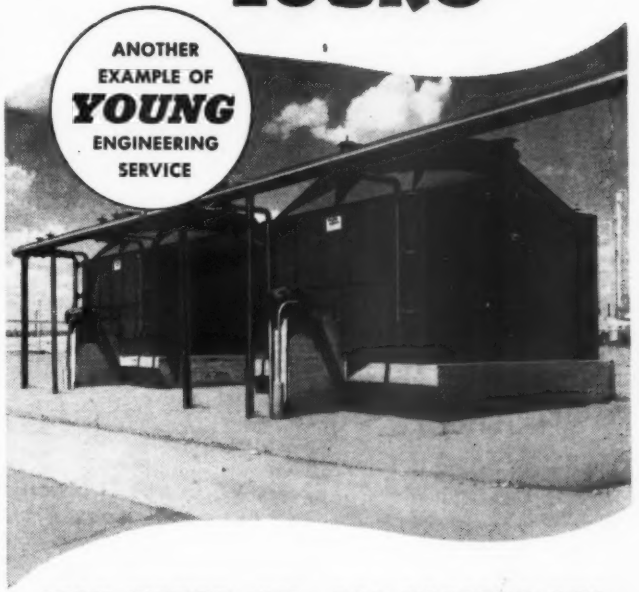
Ed Steele is an authority on drilling muds, having spent many years with Bell and Loffland as chief mud engineer. He was California sales division manager for Baroid Sales before taking over the San Joaquin Valley territory for Oil Base, Inc.

FOR YOUR BIG COOLING* JOBS

SPECIFY THE "VAD"

Vertical Air Discharge

by YOUNG



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See the "VAD" exhibited by the Happy Co., Young Mid-Continent Distributor, at the International Petroleum Exposition, Tulsa Oklahoma May 15-22, 1948.

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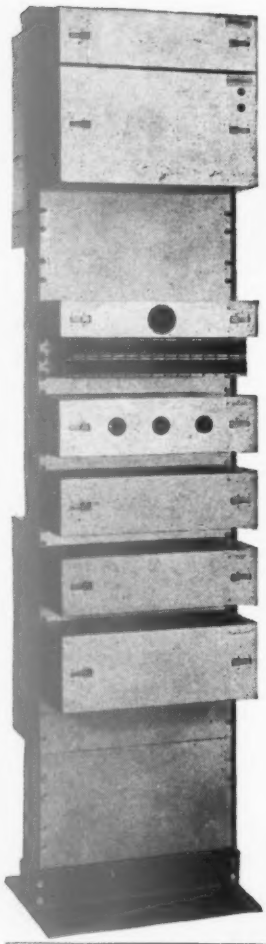

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LENKURT Knows How

National Supply Program

By the end of next year The National Supply Company will have spent more than $20,000,000 in its modernization and improvement program, an amount greater than the total net fixed assets of the company when the program was started late in 1945. This was disclosed in the company's annual report. The company manufactures oil and gas well equipment and machinery and pipe for the building industry.

In his statement to stockholders and employes, A. E. Walker, president of National Supply, reported that $10,628,000 already has been spent to modernize the company's plants and reduce costs. Approximately $7,000,000 will be needed this year and another $3,000,000 in 1949 in order to complete the program.

"The plant improvements now completed have resulted in operating economies, and it is expected that greater benefits will be realized in 1948 and more in 1949," Walker said.

With more than 33,000 oil and gas wells completed last year, and indications that an even greater number and total footage of wells will be drilled in 1948, the business outlook for National Supply is very good, Walker said.

This optimism was tempered somewhat when Walker said that "there is no assurance that another increase in wages and salaries and in the cost of raw materials and supplies would be fully covered by an increase in our selling prices. There is no doubt that a continuation of the rise in the general price level that has taken place since the end of the war, even though it is justified by increased costs, will tend to curtail demand and shorten the period of high business activity."

Net sales of the company for 1947 were $133,570,589, up more than one-third from the preceding year, to set a peacetime record. Net profit was $8,591,806, also a record. Earnings per share in the common stock outstanding at year end amounted to $5.47.

Maps coordinated sales strategy

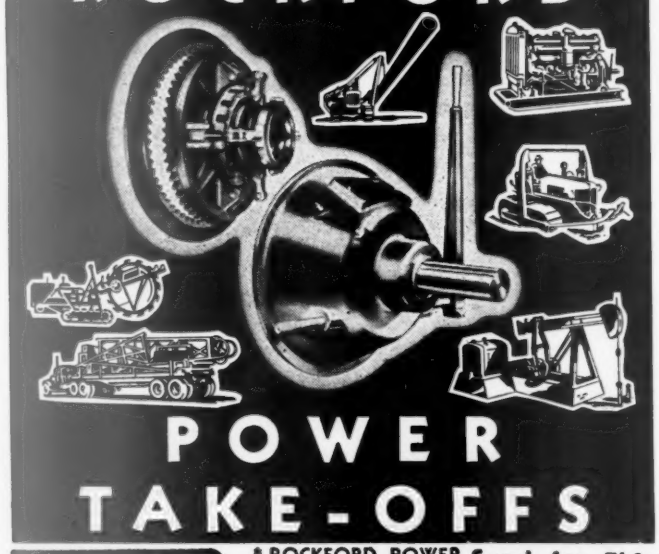
During the last 18 months many of the oil field specialties manufactured by Patterson-Ballagh have been improved upon and new rubber products have been developed. To give all their salesmen the latest information on these changes and to show them new manufacturing techniques, the executives of Patterson-Ballagh arranged to have their domestic sales organization flown to the main office and plant in Los Angeles.

The recent three-day sales meeting included a comprehensive tour through the Patterson-Ballagh plant and a field trip to see new equipment being tested. New manufacturing techniques and methods of manufacture were thoroughly explained. Each product was discussed both from the manufacturing and sales viewpoints. The salesmen made constructive suggestions that will prove valuable to the main office.

Executives of Patterson-Ballagh feel that this meeting was extremely successful in that their salesmen will now be better equipped to do a more thorough selling job in the field.

Left to right: J. P. Magoffin, district manager; Evan Sweet, Byron Jackson legal advisor; W. W. Simpson; J. M. Newton; H. H. Collins; T. M. Smith, Jr.; A. O. Wells; Bill Bonner, Jr.; W. B. Gardner. Second row: Robert Kimball; A. L. Gooden.

ROCKFORD



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FINE ADJUSTMENT
ACCURATE BALANCE
S.A.E. DIMENSIONS

* ROCKFORD POWER TAKE-OFFS are equipped with roller bearings of ample proportions to carry the loads to be placed upon them. Provision is made for adjusting the tapered roller bearings that support the shaft. These and the clutch release bearing can be lubricated from outside the housing.

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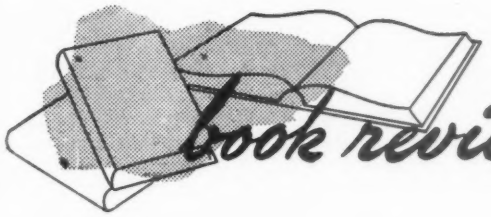

● **Russian-English Technical and Chemical Dictionary,** *by Ludmilla Ignatiev Callaham. John Wiley and Sons, 440 Fourth Avenue, New York 16. Pages, 794. Price, $10; in Canada, $12.*

This comprehensive Russian technical and chemical dictionary now makes it possible for English speaking research and technical workers to receive more than a literal translation of Soviet publications of experiments. Accuracy of definition and consistency of organization were the prime objectives and make this compilation invaluable and most up-to-date.

It provides a complete coverage of terms in organic and inorganic chemistry, chemical technology and mineralogy; extensive coverage of metallurgy, mining, geology, engineering, physics, botany, pharmacy, machinery, mechanics; and more common terms in agriculture, entomology, medicine, aeronautics, meteorology and military science. Terms of particular value to the industrial technologists are included.

A dictionary of considerable value to chemists, engineers, and other scientists interested in consulting the original Russian sources.

● **Well Logging Methods Conference,** *Bulletin 93, Engineering Experiment Station, A. & M. College of Texas, College Station, Texas. Pages, 174. Price, no charge for individual copies; multiple copies, 25 cents each.*

The department of petroleum engineering held this Well Logging Methods Conference in March, 1946. Lectures given by outstanding men in the industry are presented in this bulletin.

Mud analysis logging, mechanical well logging, temperature logging and geochemical well logging were discussed by the men familiar with their operation. Fundamentals of electrical logging were presented, followed by a discussion. Interpretation of electrical logs was explained.

Applications of the spontaneous potential dipmeter electric pilot and a well logging bibliography comprise the closing chapters of this helpful booklet for men of the industry.

● **Powder Metallurgy,** *by Henry H. Hausner. Chemical Publishing Company, 26 Court Street, Brooklyn 2, New York. Pages, 298. Price, $7.*

New physical properties in metals can be expected by using powder metallurgical methods, a recently developed branch of metallurgy. Principles of this new field are described by tables and graphs. A bibliography of 1064 references and a complete glossary of terms facilitate study. Physical and engineering properties of the metal compact and power metallurgical products are given. Results of experiments with their accompanying conditions make possible duplication for full understanding of this field.

● **Varnished Cloths for Electrical Insulation,** *by H. W. Chatfield and J. H. Wredden. Chemical Publishing Company, 26 Court Street, Brooklyn 2, New York. Pages, 255. Price, $6.*

Information formerly scattered throughout technical journals combined with data from the authors' own researches make this an important reference book on varnished insulating cloths. Processes and properties of the cloth and the contribution of varnish to the evolution of a flexible electrical insulator are told. Electrical engineers and designers are aided by learning of the material they use and what they may expect of it in the future.

● **Modern Polishes and Specialties,** *by W. D. John. Chemical Publishing Company, 26 Court Street, Brooklyn 2, New York. Pages, 313. Price, $7.50.*

Results of the author's long experience and actual laboratory and industrial experiments combine to give the reader the history, preparation, uses, manufacturing and technical data of polishes. Seven hundred modern formulae help develop and improve polish preparations. Technicians, individuals, and prospective manufacturers will find exhaustive information in this new book.

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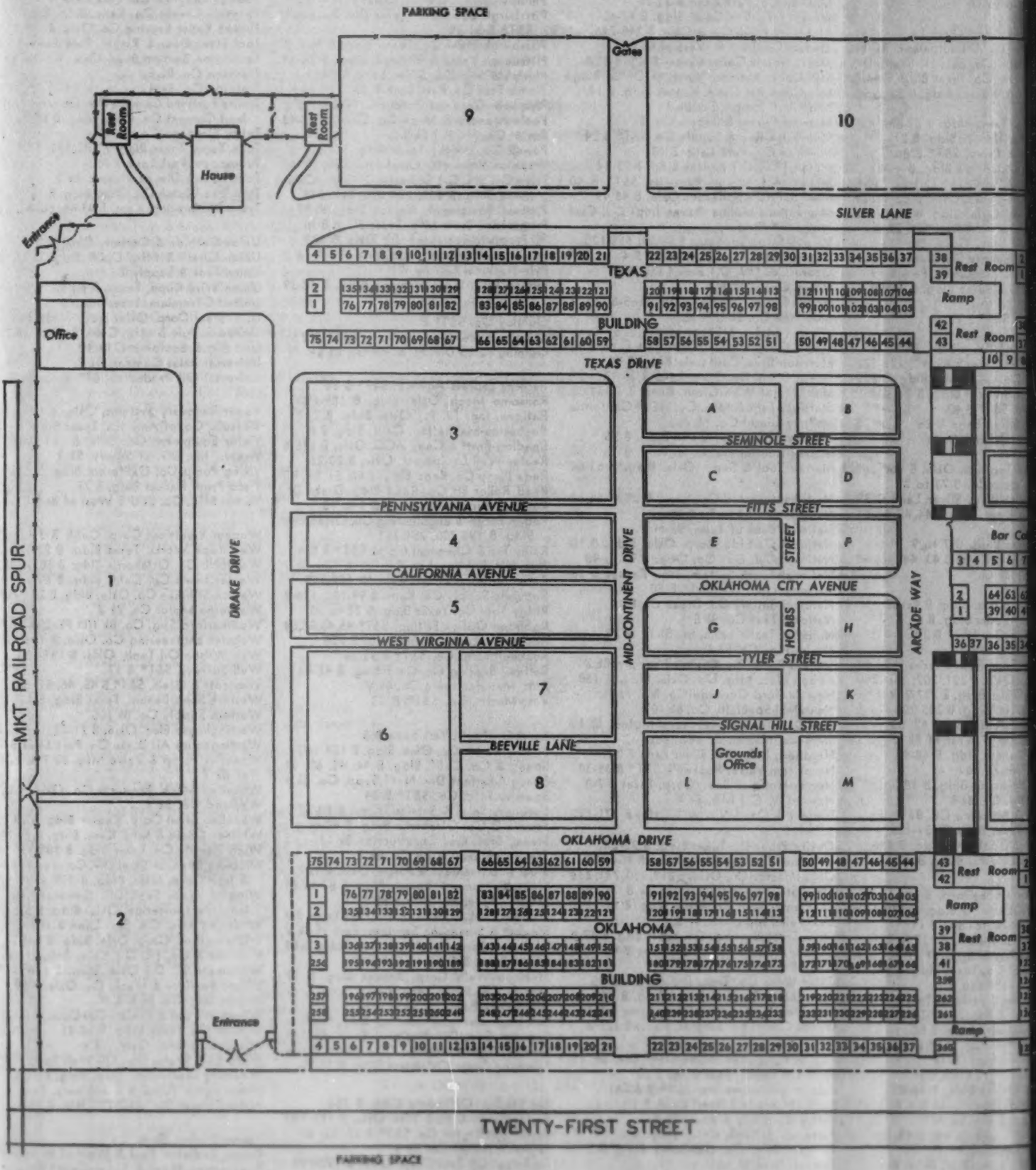

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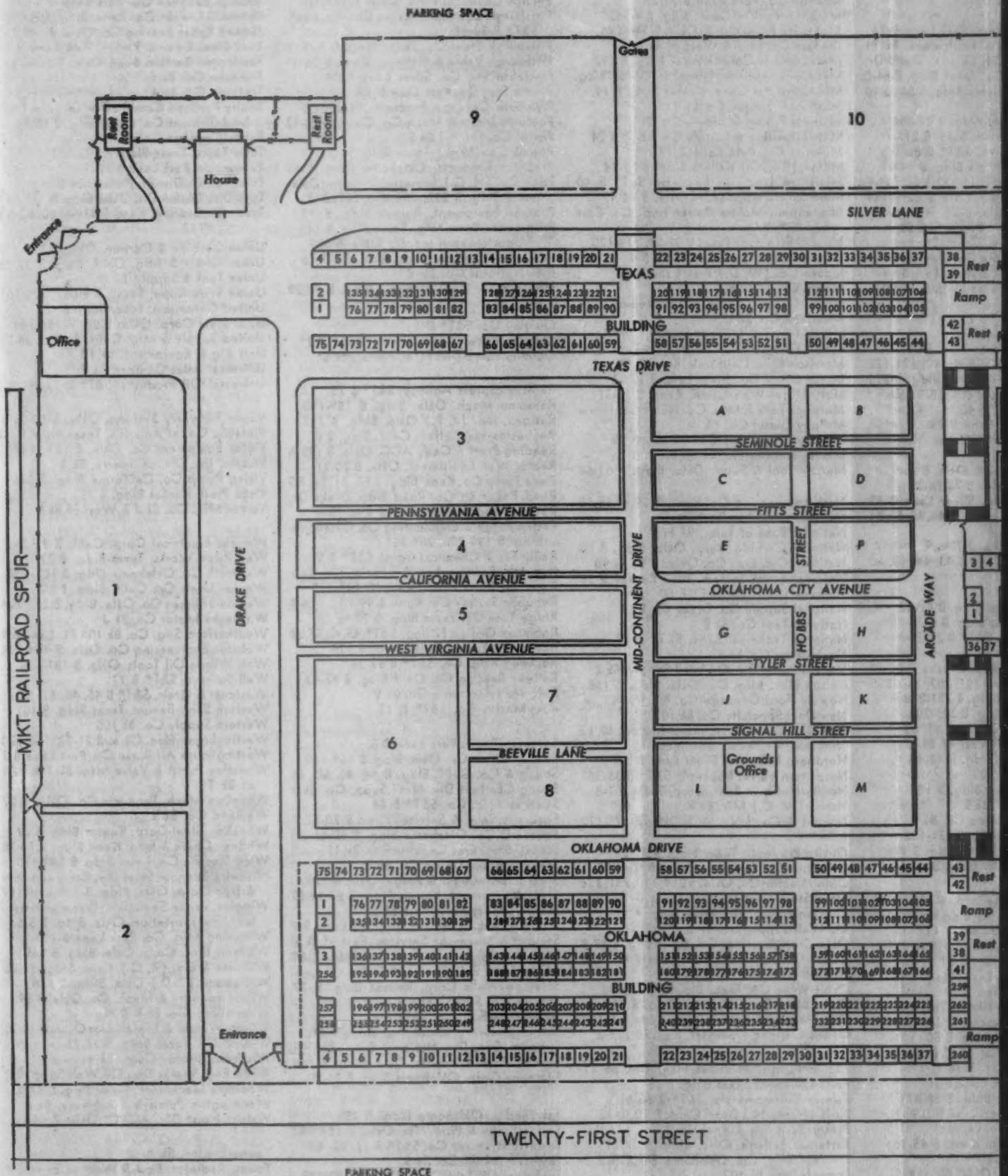

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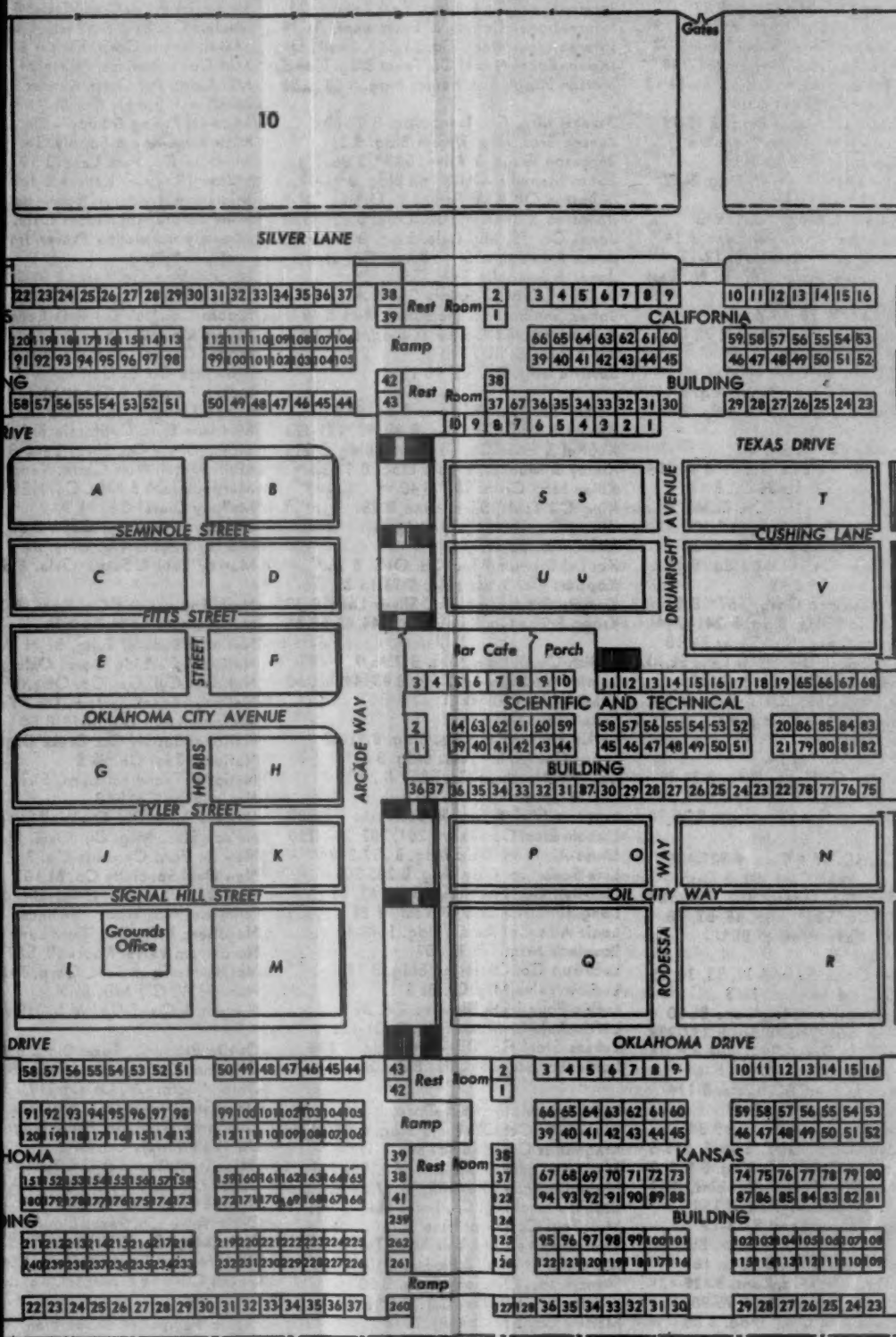

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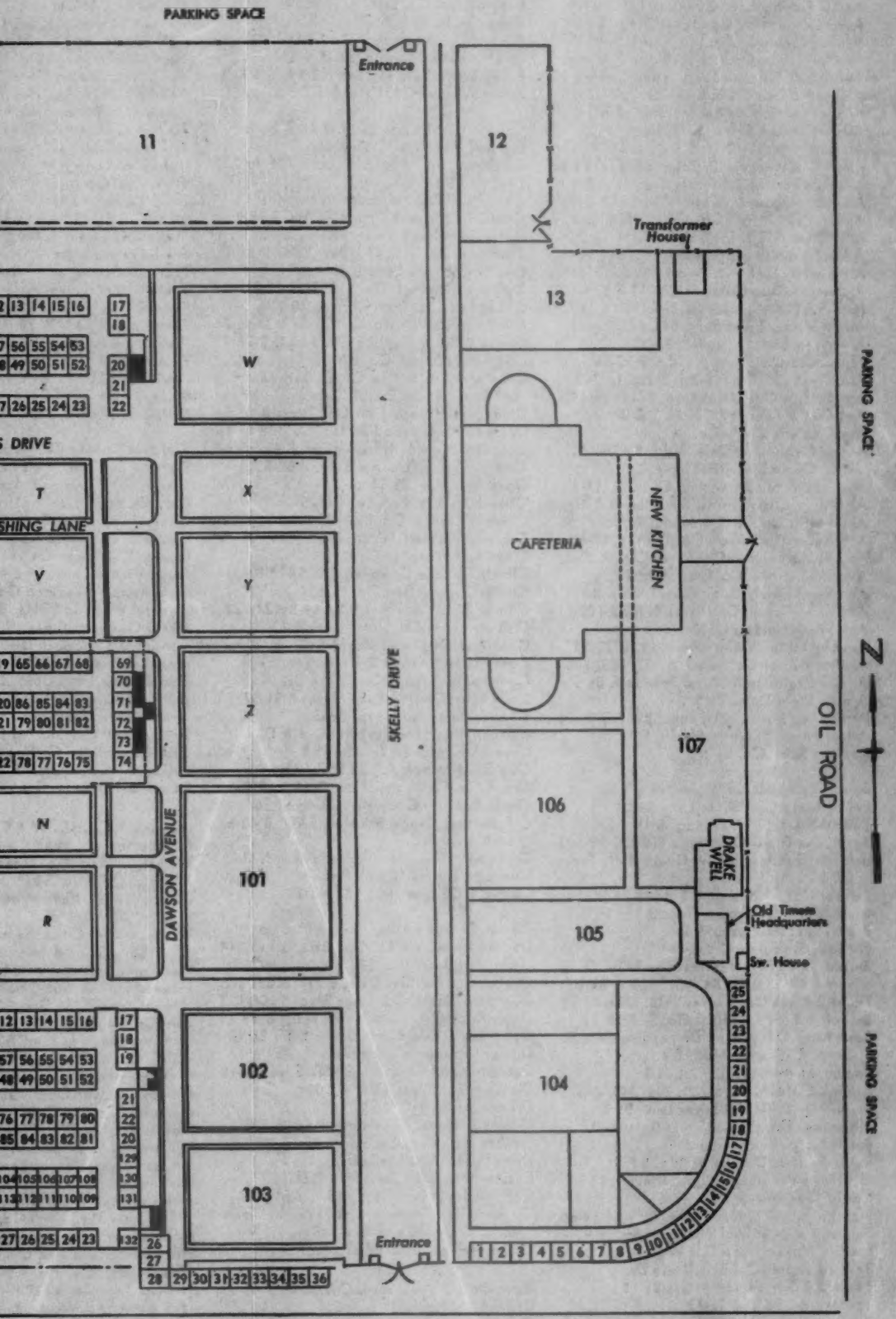

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Brewster Co. Silver Lane Bk 10
Bristol Co. S&T* B 15-16
Brodie Co. (Ralph N.) Calif. Bldg. B 54-55
Brown Instrument Co. S&T* B 41 to 43
Bruce-Macbeth Engine Co. Bk G
Bryant Heater Co. Bk 11
Bucyrus-Erie Co. Bk 4
Buda Co. Bk M
Bunting Brass & Bronze Co. S&T* B 40
Burch Agate Torpedo, S&T* B 81
Butler Mfg. Co. Kans. Bldg. B 3 to 6 & Bk H
Byron Jackson Co. Okla. Bldg. B 22-27

Cal-Fin Co. Kansas Bldg. B 25
Camco, Inc. Silver Lane B 41
Cameron Iron Works. Okla. B 225 to 228
Cardwell Mfg. Co. Bk Q
Carter Oil Co. Adjacent to Science
Catawissa Valve & Fittings. Okla. B 28-9
Caterpillar Tractor Co. Bk C & E
Cathodic Servicing Co. Park Lane B 18
Cavins Co. Park Lane B 31
Century Geophys. Corp. S&T* B 62 Bk 104
Chain Belt Co. Texas Bldg. B 70-71
Chapman Valve Mfg. Co. Texas B 24 to 26
Chase Brass & Copper Co. Texas. B 76-77
Chemical Process Co. Bk 1
Chevrolet Motor Div. GMC. Between Hall of Science and Exhibit Office
Chicago Bridge & Iron Co. Texas B 85-86
Chicago Pneumatic Tool Co. Calif. B 14-15
Chicago Rawhide Mfg. Kansas. B 43-5 & 66
Chiksan Co. California Bldg. B 52-53
Clark Bros. Co. Bk 11
Clark Mfg. Co. Park Lane B 15
Clayton Mark & Co. Bk 6, 7, 8
Cleveland Diesel Eng. GMC. Silver Bk 10
Cleveland Trencher Co. Bk P
Climax Flexible Coupling Co. S&T* B 40
Climax Engineering Co. Bk 107
Climax Eng. Co. Texas B-83-84 & 127-128
Coffing Hoist Co. Silver Lane B 12
Construction Mach. Corp. Bk 3, 6, 7, 8
Continental Motors Corporation. Bk P
Continental Supply Co. Drake Dr.
Cook Mfg. Co. (C. Lee). Texas B 51-52
Cooper-Bessemer Corp. Bk G
Cooper, Inc. (Fred E.) Bk A, B & D
Core Laboratories, Inc. S&T* B 4
Coy Co. (Joseph A.) S&T* B 63-64
Crane Co. Oklahoma Bldg. B 196-7 254-5
Crane Packing Co. Kansas Bldg. B 26
Crosby Stm. Gage & Valve, S&T* B 45-6, 57-8
Crose Mfg. Co. (M. J.) East of Kans. Bldg.
Cummins Engine Co. Bk 104
Curtin & Co. (W. H.) S&T* B 79

Daniel Orifice Fitting Co. S&T* B 86
Darling Valve & Mfg. Co. Okla. B 113-114
Davis Regulator Co. S&T* B 45-6, 57-8
Dayton Rubber Co. Okla. B 211 & Bk 8
Dearborn Chem. Co. Texas Bldg. B 106-107
Deep Rock Oil Corp. Kans. Bldg. B 28-29
Delco-Remy Div. Corp. Silver Lane Bk 10
De Luxe Products Corp. Bk 3
Detroit Diesel Eng. Div. GMC. Silver Bk 10
Dia-Log Co. Silver Lane B 10
Diamond Chain Co. S&T* B 11-12
Dollinger Corp. Oklahoma Bldg. B 207
Double Seal Ring Co. Park Lane B 16
Dowell, Inc. Bk Y, Skelly Dr.
Dresser Mfg. Div. Dresser Ind. Bk 11
Duff-Norton Mfg. Co. Okla. B 154-155
Du Pont de Nemours & Co. (E. I.) Texas Bldg. B 96-100 and 111-115
Durametallic Corp. Texas Bldg. B 14

Eastman Oil Well Surv. Co. S&T* B 44-59
Edward Valves, S&T* B 33-38
Electric Hose & Rubber Co. Okla. B 62
Elliott Co. Oklahoma Bldg. B 125-126
Emerol Mfg. Co. Okla. Bldg. B 123-124
Emsco Derrick & Equip. Co. Bk 1, 3, 6, 7, 8
Enardo Foundry & Mfg. Co. Okla. B 163
Engineering Labs. S&T* B 22 & 78 & Bk 104
Ensign Carburetor Co. Texas Bldg. B 69

Faber Engineering C
Fafnir Bearing Co. S
Failing Supply Co. (
Fairbanks Co. Califor
Fairbanks, Morse & C
Magneto Sales, Ka
Farrel-Birmingham C
Farris Engineering Co
Fawick Airflex Co. Ol
Findlay Div. of Gar W
Fischer & Porter Co.
Fisher Governor Co.
Fitler Co. (Edwin H.)
Flint Steel Corp. S&T
Fluid Packed Pump C
Fluor Corp. S&T* B 47
Foote Bros. Gear & M
Formica Insulation C
Foster Cathead Co.
Four Wheel Drive A
of Bk N
Foxboro Co. S&T* B
France Packing Co. T
Franks Mach. Co. Bk
Franks Mfg. Corp. Bk
Frost Geophysical Co
Fulton Sylphon Co. C

Gardner-Denver Co.
Garrett Oil Tools, Pa
Gar Wood Industries
Gaso Pump & Burner
Gates Rubber Co. Te
Gatke Corp. Calif. B
Gemco Oil Tools, Ol
Geolograph Co. S&T
Geophysical Researc
General Elec. Co. Ol
GMC Overseas Ope
GMC Truck & Coach
Geophoto Services, C
Geophysical Dev. Co
Goode Equip. Co. Te
Great Lakes Steel Co
Greb X-Ray Co. S&T
Grove Regulator Co.
Guiberson Corp. Okl
Gustin-Bacon Mfg. C

Haering & Co. (D. W
Halliburton Oil Well
Hamer Oil Tool Co.
Hammel-Dahl Co. S
Happy Co. Bk J and
Harley Sales Co. Bk
Harnischfeger Corp.
Harrisburg Sales & S
Harrison Radiator Di
Haynes Stellite Co.
Hazard Wire Rope D
Heil Co. Bk 102
Helicord Gage Div.
Heinn Co. California
Hendershot Tool Co.
Hercules Motor Cor
Hercules Tool Co. C
Hewitt Rubber Div.,
Hilliard Corp. Oklah
Hillman-Kelley, Silve
Hinderliter Tool Div.
Hobart Bros. Kansas
H & M Pipe Bev. Ma
Hollup Corp. Oklaho
Hopeman Equip. Co
Hough Mfg. Co. Te
Hughes Tool Co. Bk
Hutchison Eng. Wor
Hyatt Bearing Div.
Hydraulics Div. Rock
Hydril Co. Bk F, B 1
Hyster Co. Bk G

Independent-Eastern
Independent Supp.

Abbreviations: B—Booth; Bk.—Block; S&T*—Science and Technical Building.

Engineering Co. Calif. Bldg. B 4-5
Bearing Co. S&T* B 40
Supply Co. (Geo. E.) Bk 10
nks Co. California Bldg. B 50-51
nks, Morse & Co. Calif. B 10-13 Inc.
gneto Sales, Kansas Bldg. B 37
Birmingham Co. Okla. Bldg. B 191
Engineering Corp. Silver Lane B 32
Airflex Co. Okla. Bldg. B 257-258
y Div. of Gar Wood Industries, Bk 13
r & Porter Co. S&T* B 25
Governor Co. Texas Bldg. B 78-79
Co. (Edwin H.) Texas Bldg. B 4
teel Corp. S&T* B 20-21
Packed Pump Co. Calif. Bldg. B-12
Corp. S&T* B 47-48
Bros. Gear & Mach. Co. Bk G
a Insulation Co. Silver Lane B 14
Cathead Co. Texas Bldg. 12-13
Wheel Drive Auto Co. Bk N, East
k N
o Co. S&T* B 18, 19 & 65
Packing Co. Texas Bldg. B 72
Mach. Co. Bk 104
Mfg. Corp. Bk Z
Geophysical Corp. Okla. Bldg. B 161
Sylphon Co. Oklahoma Bldg. B 170

er-Denver Co. Bk 3 & 8
t Oil Tools, Park Lane B 11 & Bk 104
Wood Industries, Skelly Dr. B 13
Pump & Burner Mfg. Co. Bk W
Rubber Co. Texas Bldg. B 9-10
Corp. Calif. Bldg. B 23, 24, 25
o Oil Tools, Oklahoma Bldg. B 19
graph Co. S&T* B 49
ysical Research Corp. S&T* B 51
al Elec. Co. Okla. Bldg. B 241–244
Overseas Oper. Div. Silver Bk 10
Truck & Coach Div. Silver Lane Bk 10
oto Services, Okla. Bldg. B 162
ysical Dev. Corp. Okla. Bldg. B 161
Equip. Co. Texas Bldg. B 5
Lakes Steel Corp. Bk 107
X-Ray Co. S&T* B 24
Regulator Co. Texas Bldg. B 36-37
rson Corp. Okla. B 217, 218, 233, 234
-Bacon Mfg. Co. Silver Lane B 25-26

g & Co. (D. W.) Kans. B 127-128
urton Oil Well Cem. Bk & East
r Oil Tool Co. Texas B 102, 103, 108
el-Dahl Co. S&T* B 45, 46, 57, 58
y Co. Bk J and West of Bk U
y Sales Co. Bk 4
chfeger Corp. Kans. B 32, 33, 34, 35
burg Sales & Service, Bk 3
on Radiator Div. Silver Lane Bk 10
s Stellite Co. Okla. Bldg. B 237-238
d Wire Rope Div. AC&C. Texas B 7-8
Co. Bk 102
rd Gage Div. AC&C. Okla. B 174
Co. California Bldg. B 49
rshot Tool Co. Silver Lane B 34
les Motor Corp. Okla. B 76-8, 133-5
les Tool Co. California Bldg. B 7, 8, 9
t Rubber Div., Hewitt-Robbins, Bk 3
rd Corp. Oklahoma Bldg. B 153
an-Kelley, Silver Lane B 18-19
rliter Tool Div. H. K. Porter, Bk 5
rt Bros. Kansas Bldg. B 10 to 16
Pipe Bev. Mach Co. Kans. B 129-131
o Corp. Oklahoma Bldg. B 95-98
man Equip. Co. Okla. Bldg. B 88
h Mfg. Co. Texas Bldg. B 123-124
es Tool Co. Bk 106
ison Eng. Works. Kans. Bldg. B 79-80
Bearing Div. GM. Silver Lane Bk 10
ulics Div. Rockwell Mfg. S&T* B 33-38
Co. Bk F, B 1
r Co. Bk G

endent-Eastern Torpedo Co. Bk L
endent Supp. Co. Kans. B 32-35 Inc.

Indian Drilling Mud Co. Calif. Bldg. B 42
Industrial Sales & Eng. Kans. B 43-5, 60-3
Industrial X-Ray Engrs. Okla. Bldg. B 221
Ingersoll-Rand Co. Bk U
Insley Mfg. Co. Bk 9
International Cementers, Park Lane B 24
International Derrick & Equipment, Bk 11
International Harv. Co. Bk 101, Skelly Dr.
International Nickel Co. Texas Bldg. B 64-5
Iverson Supply Co. Kansas Bldg. B 88 to 90

Jerocki Mfg. Co. Texas Bldg. B 87-88
Jensen Bros. Mfg. Kansas Bldg. B 21
Jerguson Gage & Valve, S&T* B 86
Johns-Manville, Oklahoma Bldg. B 44-47
Johnston Oil Field Serv. (M. O.) Bk 104-F
Johnston & Jennings Co. Okla. B 82 & 129
Jones Co. (S. M.) Okla. Bldg. B 15-16
Jones & Laughlin Steel Barrel Co. Bk I
Jones & Laughlin Steel Corp. Bk. I
Jones & Laughlin Supply Co. Bk I
Jones, Shelburne & McGuffey, Park B 19
Joyce-Cridland Co. Texas Bldg. B 49-50
Joy Mfg. Co. Bk 7
Justrite Mfg. Co. S&T* B 17

Kelley Co. (Ben F.) Texas Bldg. Bk 3
Kerotest Mfg. Co. Okla. B 89, 90, 121-122
Keuffel & Esser Co. Oklahoma Bldg. B 213
Kieley & Mueller, Kansas Bldg. B 81-82
Kilian Mfg. Corp. S&T* B 40
King Oil Tools, Silver Lane B 25
Kinley Co. (M. M.) Silver Lane
Kobe, Inc. Bk 11
Koebel Diamond Tool Co. Okla. B 260
Koppers Co. Texas Bldg. B 73 to 75
Korkola Production Eng. Silver Lane B 39
Kropp Forge Co. Kans. Bldg. B44, 45, 60, 61

Ladish Co. Kansas Bldg. B 7 to 9
Laminated Shim Co. Kans. B 43, 44, 45, 60
Landry (Max E.) Bk G
Lane-Wells Co. Bk V
Larkin Packer Co. Okla. Bldg. B 51-52
Lebus Co. (F. L.) Texas Bldg. B 8
Leeds & Northrup Co. S&T* B 29-30
Le Roi Co. Bk R
Leschen (A.) & Sons Rope. Texas B 31-32
Lincoln Elec. Co. Okla. B 201, 202, 240, 250
Linde Air Prod. Okla. Bldg. B 237-238
Line Scale Co. Okla. Bldg. B 205-206
Link-Belt Co. Texas Bldg. B 61, 62, 63
Long (Jon R.) Bk J & West of Bk U
Louis Allis Co. Kansas Bldg. B 48-49
Lovelace Mfg. Co. Bk 107
Lubrikup Co. Oklahoma Bldg. B 184
Ludlow Valve Mfg. Co. Bk 3
Lufkin Foundry & Machine Co. Bk 3
Lufkin Rule Co. Texas Bldg. B 121-122
Lukens Steel Co. Oklahoma Bldg. B 195
Lunkenheimer Co. Okla. Bldg. B 67-68

Mack-Int. Motor Truck Corp. B 104
Macwhyte Co. Oklahoma Bldg. B 130-131
Magnaflux Corp. Silver Lane B 11
Magneto Ignition Co. Kans. B 129 to 131
MagniLastic, Kansas Bldg. B 17
Magnus Chemical Co. Texas Bldg. B 46
Mall Tool Co. Silver Lane B 38
Maloney-Crawford Tank Mfg. Tex. B 116-7
Manning, Maxwell & Moore, Okla. B 230
Manzel, Inc. Oklahoma Bldg. B 50
Maples & Co. (Steve C.) S&T* B 5-6
Marley Co. Kansas Bldg. B 78
Martin Supply Co. Park Lane B 36
Marlow Pumps, Kansas Bldg. B 86-87
Marman Prod. Co. Silver Lane B 8-9
Marmon-Herrington Co. Bk W
Marshall Supp. & Equip. Kans. B 95-96
Martin-Decker Corp. Bk 4
Martin (John N.) Mfr. Okla. Bldg. B 41
Maxim Silencer Co. Bk 6, 7, 8
Mayhew Mach. & Supply, Bk 107 & Southeast of Cafeteria

McCord Corp. Oklahoma Bldg.
McCullough Tool Co. Calif. Bld
McDonald Co. (B. F.) Texas Bld
McEvoy Co. Park Lane B 27-28
McGill Mfg. Co. Calif. Bldg. B
McKissick Prod. Corp. Okla. B 2
Medart Co. Bk J & West of Bk U
Metal Goods Corp. Kansas Bldg
Mid-Cont. Airlines, North of O
Mid-Cont. Pet Corp. Kansas Bld
Mid-Cont. Supply Co. Bk 3
Midwest Piping & Supply Co. Bk
Midwest X-Ray & Supply Co. S&
Milwhite Co. Park Lane B 13
Milton (Roy C.) Kansas Bldg. B
Miniature Precision Bearings, S
Mine Safety Appliances Okla. B
Minneapolis-Moline Power Imp. of S&T* Bldg.
Mission Mfg. Co. Texas B 91-93,
Mixing Equip. Co. Calif. Bldg. B
Moore Co. (W. D.) Park Lane B
Moore Co. S&T* B 3
Moore Corp. (Lee C.) Okla. B 6
Moorlane Co. Bk U
Moran Furnace & Sheet Metal, E
Morris Coupling & Clamp, Park
Morrison Bros. California Bldg. B
Morse Chain Co. Silver Lane B 1
Multi-Metal Wire Cloth, Kans. B
Murdock Tank & Mfg. Co. NE of
Murphy Diesel Co. Bk A
Murphy (Frank W) Calif. Bldg.
Murray Rubber Co. Okla. Bldg.
Murray Tool & Supp. Okla. Bldg

Nash Engineering Co. Kans. B 3
Natasco Co. S&T* B 69-70
National Bank of Tulsa, Bk H
National Carbide Corp. Okla. B
National Cyl. Gas Co. Okla. B 9
National Foam System, Inc., Ka
National Lead Co. S&T* B 50
National Supply Co. Drake Dr. B
National Tank Co. Bk S
National Technical Labs. S&T* B
Naylor Pipe Co. Bk 3
Neilson Pump Div. Oil Well Supp
Nelson Elec. Mfg. Co. Okla. Bld
New Bedford Cordage Co. B 6,
New Deal Specialty Co. Bk 107
New Departure Div. General Mot
Nomads, Northwest entrance
Nordberg Mfg. Co. Silver Lane
Nordstrom Valve, Rockwell, S&T*
Norma-Hoffman Bear. Corp. Tex
Norris (W. C.) Mfr. Bk X
Nugent & Co. (Wm W.) Okla.

Oakite Products, Texas Bldg. B 2
O'Bannon Co. (Walter) Texas B
Ohio Injector Co. Okla. B 219, 22
Ohio Steel Foundry Co. Texas
Oil Center Tool Co. Okla. Bldg.
Oil Well Supply Co. Bk 2
Okla. Steel Castings Co. Texas B
Oliver United Filters, Park Lane
Onan & Sons (D. W.) Bk T
Orbit Valve Co. Texas Bldg. B 3
Oster Mfg. Co. Oklahoma Bldg.
Otis Pressure Control, Silver Lan
Owens-Corning Fiberglas. Kans.

Pacific Pumps, Mid-Continent D
Page Oil Tools, Texas Bldg. B 13
Palmer Thermometers, S&T* B 6
Paris (Henry H.) Distr. Calif. B 2
Parkersburg Rig & Reel, Bk 8
Patterson-Ballagh, Okla. Bldg. B
Peerless Mfg. Co. Oklahoma Bl
Perrault Bros. Bk 102
Petro-Chem Development Co. Bk
Petroleum Eng. Oklahoma Bdlg.
Petroleum Equipment, S&T* B 80

Exhibitors and their booth numbers

&T*—Science and Technical Building.

o. Calif. Bldg. B 42
Kans. B 43-5, 60-3
. Okla. Bldg. B 221
U

ers, Park Lane B 24
& Equipment, Bk 11
o. Bk 101, Skelly Dr.
o. Texas Bldg. B 64-5
nsas Bldg. B 88 to 90

Bldg. B 87-88
sas Bldg. B 21
e, S&T* B 86
oma Bldg. B 44-47
v. (M. O.) Bk 104-F
o. Okla. B 82 & 129
a. Bldg. B 15-16
Barrel Co. Bk 1
Corp. Bk. 1
ly Co. Bk 1
cGuffey, Park B 19
xas Bldg. B 49-50

* B 17

xas Bldg. Bk 3
la. B 89, 90, 121-122
klahoma Bldg. B 213
sas Bldg. B 81-82
* B 40
Lane B 25
lver Lane

Co. Okla. B 250
dg. B 73 to 75
ng. Silver Lane B 39
. Bldg. B 44, 45, 60, 61

dg. B 7 to 9
Kans. B 43, 44, 45, 60

a. Bldg. B 51-52
s Bldg. B 8
. S&T* B 29-30

Rope. Texas B 31-32
. B 201, 202, 240, 250
Bldg. B 237-238
Bldg. B 205-206
dg. B 61, 62, 63
West of Bk U
Bldg. B 48-49
107
na Bldg. B 184
. Bk 3
chine Co. Bk 3
Bldg. B 121-122
homa Bldg. B 195
la. Bldg. B 67-68

k Corp. B 104
oma Bldg. B 130-131
r Lane B 11
Kans. B 129 to 131
Bldg. B 17
. Texas Bldg. B 46
Lane B 38
nk Mfg. Tex. B 116-7
Moore, Okla. B 230
a Bldg. B 50
C.) S&T* B 5-6
dg. B 78
rk Lane B 36
s Bldg. B 86-87
ver Lane B 8-9
Co. Bk W
ip. Kans. B 95-96
Bk 4
r. Okla. Bldg. B 41
k 6, 7, 8
pply, Bk 107 & South-

McCord Corp. Oklahoma Bldg. B 72-73
McCullough Tool Co. Calif. Bldg. B 17-18
McDonald Co. (B. F.) Texas Bldg. B 54
McEvoy Co. Park Lane B 27-28
McGill Mfg. Co. Calif. Bldg. B 42-43
McKissick Prod. Corp. Okla. B 245-246
Medart Co. Bk J & West of Bk U
Metal Goods Corp. Kansas Bldg. B 132
Mid-Cont. Airlines, North of Office Bldg.
Mid-Cont. Pet Corp. Kansas Bldg. B 19
Mid-Cont. Supply Co. Bk 3
Midwest Piping & Supply Co. Bk 1
Midwest X-Ray & Supply Co. S&T* B 24
Milwhite Co. Park Lane B 13
Milton (Roy C.) Kansas Bldg. B 23-24
Miniature Precision Bearings, S&T* B 40
Mine Safety Appliances Okla. B 48-49
Minneapolis-Moline Power Imp. Co. East of S&T* Bldg.
Mission Mfg. Co. Texas B 91-93, 116-120
Mixing Equip. Co. Calif. Bldg. B 4
Moore Co. (W. D.) Park Lane B 23
Moore Co. S&T* B 3
Moore Corp. (Lee C.) Okla. B 65-66
Moorlane Co. Bk U
Moran Furnace & Sheet Metal, E. of Kans.
Morris Coupling & Clamp, Park Lane B 12
Morrison Bros. California Bldg. B 58
Morse Chain Co. Silver Lane B 15-16
Multi-Metal Wire Cloth, Kans. B 30-31
Murdock Tank & Mfg. Co. NE of California
Murphy Diesel Co. Bk A
Murphy (Frank W) Calif. Bldg. B 26
Murray Rubber Co. Okla. Bldg. B 16
Murray Tool & Supp. Okla. Bldg. B 63-64

Nash Engineering Co. Kans. B 39,40,65,66
Natasco Co. S&T* B 69-70
National Bank of Tulsa, Bk H
National Carbide Corp. Okla. Bldg. B 30
National Cyl. Gas Co. Okla. B 95 to 98
National Foam System, Inc., Kansas B 38
National Lead Co. S&T* B 50
National Supply Co. Drake Dr. Bk 1
National Tank Co. Bk S
National Technical Labs. S&T* B 79
Naylor Pipe Co. Bk 3
Neilson Pump Div. Oil Well Supply, Bk 2
Nelson Elec. Mfg. Co. Okla. Bldg. B 168
New Bedford Cordage Co. B 6, 7, 8
New Deal Specialty Co. Bk 107
New Departure Div. General Motors, Bk 10
Nomads, Northwest entrance
Nordberg Mfg. Co. Silver Lane B 24
Nordstrom Valve, Rockwell, S&T* B 33-38
Norma-Hoffman Bear. Corp. Texas B 7-8
Norris (W. C.) Mfr. Bk X
Nugent & Co. (Wm W.) Okla. B 171-172

Oakite Products, Texas Bldg. B 22-23
O'Bannon Co. (Walter) Texas B 104-105
Ohio Injector Co. Okla. B 219, 220, 231, 232
Ohio Steel Foundry Co. Texas B 78-79
Oil Center Tool Co. Okla. Bldg. B 11-12
Oil Well Supply Co. Bk 2
Okla. Steel Castings Co. Texas Bdg. B 47-8
Oliver United Filters, Park Lane B 4
Onan & Sons (D. W.) Bk T
Orbit Valve Co. Texas Bldg. B 33 to 35
Oster Mfg. Co. Oklahoma Bldg. B 240
Otis Pressure Control, Silver Lane B 6-7
Owens-Corning Fiberglas. Kans. B 121-2

Pacific Pumps, Mid-Continent Div. Bk 11
Page Oil Tools, Texas Bldg. B 13
Palmer Thermometers, S&T* B 60-61
Paris (Henry H.) Distr. Calif. B 20 to 22
Parkersburg Rig & Reel, Bk 8
Patterson-Ballagh. Okla. Bldg. B 22-27
Peerless Mfg. Co. Oklahoma Bldg. B 216
Perrault Bros. Bk 102
Petro-Chem Development Co. Bk 9
Petroleum Eng. Oklahoma Bdlg. B 222
Petroleum Equipment, S&T* B 80
Petroleum Engineer Publishing Co. Bk 2
Petroleum Solvents Co. Bk 3
Pfeudler Co. Kansas Bldg. B 52-53
Phillips Chemical Prod. Okla. B 151-152
Pittsburgh Equitable Meter Div. Rockwell, S&T* B 33-38
Pittsburgh Steel Co. Texas Bldg. B 4, 5, 6
Pittsburgh Valve & Fittings. Silver B 36-37
Plastelite Eng Co. Silver Lane B 14
Plomb Tool Co. Park Lane B 23
Plymouth Cordage Products, Bk 2
Poole Foundry & Mach Co. Calif. B 42-43
Porter Co. (H. K.) Bk 5
Powell Co. (Wm.) Texas Bldg. B 1-2
Precision Products, Oklahoma Bldg. B 42
Price Co. (H. C.) Somastic Division, Oklahoma Bldg. B 203, 204 and 247, 248
Process Equipment, Kansas Bldg. B 77
Progressive Brass Mfg. Texas Bldg. B 11
% Proportioneers, Inc. %. Okla. B 329
Purolator Products, Okla. Bldg. B 17-18
Pyle-National Co. Bk V
Pyrene Mfg. Co. Oklahoma Bldg. B 38-39

Quigley Co. S&T* B 1
Quigley Panel Constructions, S&T* B 2
Quimby Pump Div. H. K. Porter, Bk 5

Railway Express Agency, S&T* B 28
Ransome Mach. Okla. Bldg. B 189-190
Ratigan, Inc. (J. P.) Okla. Bldg. B 212
Raybestos-Manhattan, Calif. Bldg. B 6
Reading-Pratt & Cady ACC. Okla. B 175-6
Rector Well Equipment, Okla. B 20-21
Reda Pump Co. Kans. Bldg. B 50, 51, 54, 55
Reed Roller Bit Co. Reed Bldg. Drake Dr.
Refinery Supply Co. S&T* B 8 to 10
Regan Forge & Engineering Co. Oklahoma Bldg. B 198-200, 251-253
Reilly Tar & Chemical Corp. S&T* B 5-6
Republic Rubber, Lee Rubber & Tire Bk 1
Republic Steel Corp. Kans. B 102-115
Republic Supply Co. Kans. B 99-101, 116-8
Ridge Tool Co. Texas Bldg. B 28 to 30
Robinson Orifice Fitting. S&T* 45,46,57,58
Rochester Ropes, Texas Bldg. B 125
Rockwell Mfg. Co. S&T* B 33-38
Rollway Bearing Co. Calif Bldg. B 42-43
Rolo Manufacturing Co. Bk V
Ross-Martin Co. S&T* B 13

Snap-On Tools, Park Lane B 5
Sonner Burner Co. Okla. Bldg. B 159-160
Spang & Co. Calif. Bldg. B 44, 45, 60, 61
Spang-Chalfant Div. Nat'l Supp. Co. Bk 1
Sparkler Mfg. Co. S&T* B 14
Specialty Sales & Service, Kans. B 20-22
Square D Co. Oklahoma Bldg. B 60-61
Stacey Bros. Gas Construction Bk 11
Standco Brake Lining Co. Bk 3
Steel Improvement & Forge, Okla. B 229
Stentz Equipment, Kansas Bldg. B 83 to 85
Sterling Machinery, East of Bk T
Sterling Pack. & Gasket Co. Park Lane B 7
Stewart & Stevenson Services, East of Bk V
St. Louis Cordage Mills, Texas Bldg. B 89
Strom Steel Ball Co. S&T* B 40
Struthers-Wells Corp. Kansas Bldg. B 77
Stoody Co. Silver Lane B 43
Subsurface Eng. Co. S&T* B 23
Sun Engineering, Oklahoma Bldg. B 87
Superior Eng. Div. National Supp. Bk 149
Synchro-Start Products, Okla. Bldg. B 164
Synthane Corp. Oklahoma Bldg. B 74-75

Tal Bender, Oklahoma Bldg. B 256
Taylor Forge & Pipe Wks. Okla. B 189-190
Taylor Instrument Co. S&T* B 31, 32, 87
Taylor Winfield Co. Bk 9
Technical Oil Tool Corp. Okla. B 192-193
Telematic Corp. Kansas Bldg. B 64
Texas Rubber Specialty Corp. Bk 3
Texoma Supply Co. B 69, 70, 71
Thermoid Co. Silver Lane B 28
Thew Shovel Co. next to Hall of Science
Thompson Pump Co. Okla. Bldg. B 132
Thomas Laughlin Co. Park Lane B 8
Thornhill-Craver Co. Kans. Bldg. B 67-72
Timken Roller Bearing Co. Okla. B 149-150
Tool Steel Gear & Pinion, Park Lane B 2
Torrington Bantam Bear. Okla. B 185-186
Treckson Co. Bk E
Tretolite Co. Bk 4
Trinity Portland Cement Div. General Portland Cement Co. Okla. Bldg. B 85-86
Tubbs Cordage Co. Bk 9
Tube Turns, Texas Bldg. B 132-133
Tuboscope, Park Lane B 30
Tulsa Winch Div. of Vickers, Bk 3
Twin Disc Clutch Co. Okla. Bldg. B 166-167
Tyson Rlr. Bearing. Kans. B 43-45, 60, 62, 63

Union Carbide & Carbon, Okla. B 237-238
Union Chain & Mfg. Calif. Bldg. B 37-38
Union Tank & Supply, Bk H
Union Wire Rope, Texas, B 80-82, 129-131
United Chromium, Texas Bldg. B 126
U. S. Steel Corp. Okla. Bldg. B 136-148
United Supply & Mfg. Calif. Bldg. B 28-29
Unit Rig & Equipment, Bk 12
Universal Atlas Cement, Bk 2
Universal Oil Products, S&T* B 73-74

Vapor Recovery Systems, Okla. B 80-81
Victaulic Co. of America, Texas Bldg. B 90
Victor Equipment Co. Okla. B 189-190
Vickers, Inc. Div. of Sperry, Bk 3
Viking Pump Co. California Bldg. B 57
Visco Prod. Kansas Bldg. B 73
Vortex Mfg. Co. Bk J & West of Bk U

Wagner Electrical Corp. Calif. B 35-36
Wall Rope Works, Texas Bldg. B 27
Walworth Co. Oklahoma Bldg. B 103-108
Warner Lewis Co. Calif. Bldg. B 59
Watson-Stillman Co. Okla. Bldg. B 223-224
Waukesha Motor Co. Bk J
Weatherford Spg. Co. Bk 104 Pk. Lane B 9
Webster Engineering Co. Okla. B 194-195
Web Wilson Oil Tools, Okla. B 187-188
Well Surveys, S&T* B 77
Westcott & Greis, S&T* B 45, 46, 57, 58
Western Sand-Banum, Texas Bldg. B 101
Western Supply Co. Bk 105
Westinghouse Elec. Okla. B 21-23, 118-120
Westinghouse Air Brake Co. Park Lane B 3
Wheatley Pump & Valve Mfg. Bk T & East of Bk T
Wheeling Mach. Products Co. Okla. B 22
Wheland Co. Bk 1
Wheeling Steel Corp. Kansas Bldg. B 27
Whitney Chain & Mfg. Kans. Bldg. B 74-75
Wico Electric Co. Texas Bldg. B 109-110
Wickwire Spencer Steel Div. Colorado Fuel & Iron Corp. Okla. Bldg. B 109 and 119
Wiggins Vapor Seals Div. General American Transportation, Okla. Bldg. B 5-6
Wilkening Mfg. Co. Park Lane B 10
Williams Bros. Corp. Okla. Bldg. B 165
Williams & Co. (R. C.) Kans. Bldg. B 126
Williamson (T. D.) Okla. Bldg. B 156
Wilson Foundry & Mach. Co. Okla. B 59
Wilson Mfg. Co. Bk R & N
Wilson Welder & Metals Co. Okla. B 34-35
W-K-M Co. Texas Bldg. B 18-21
Wisconsin Motor Corp. Bk 4
Witte Eng. Works Div. Oil Well Supp. B 2
Woobank Machinery, Texas Bldg. B 51-52
Worthington Pump & Machinery, Bk 9
Wright Hoist Div. AC&C. Okla. B 158

Young Engine, Bk A
Young Radiator, Bk J & West of Bk U
Youngstown Sheet & Tube. Cont'l Bldg.

Zink Company (John) Silver Lane B 3-4